NATIONAL INSTITUTE OF TECHNOLOGY
ANDHRA PRADESH

SCHEME OF INSTRUCTION AND SYLLABI

B.Tech. METALLURGICAL AND MATERIALS ENGINEERING

Effective from 2020-21

Contents

NATIONAL INSTITUTE OF TECHNOLOGY ANDHRA PRADESH

Vision of the Institute

To nurture and produce highly competent engineers, scientists and entrepreneurs committed towards catering to futuristic societal challenges through holistic education synergetic with innovations and vibrant research eco-system.

Mission of the Institute

- To implement best practices in teaching-learning methodologies for establishing dynamic knowledge-connected society.
- To create a conducive environment for carrying out research in multi-disciplinary areas and thereby nurturing novel thinking capabilities.
- To strengthen industry-institute interface to inculcate entrepreneurship abilities.
- To address all technological needs of the Nation for self-sustenance.

DEPARTMENT OF METALLURGICAL AND MATERIALS ENGINEERING

Vision of the Department

The vision of the Department is to impart profound fundamental and applied knowledge in materials science and metallurgy to the prospective engineers and to enable them to embark on a challenging career in versatile domains encompassing production, research and development, and thereby evolve as a knowledge center that is unique in scope and unsurpassed in dedication to its students and the nation.

Mission of the Department

- To motivate graduates and provide them high-quality education and hands-on training in Metallurgy and Materials Science for productive careers in engineering and allied fields.
- To encourage graduates to discover and disseminate new knowledge through creative activity in novel materials research.

- To engage in collaborative research with academia, R&D and industry partners and extend our expertise for research, testing and consultancy.
- To provide service to the state, nation, and world by advancing the frontiers of materials technology and to enhance the human condition.

Department of Metallurgical and Materials Engineering:

About the Department:

The Department of Metallurgical and Materials Engineering is progressing at a rapid pace with development in both infrastructure and academic programmes. The department has highly qualified faculty members with research interests in the following areas: Extractive Metallurgy; Metallurgical Waste Utilization; Welding Metallurgy; High Temperature Corrosion; Additive Manufacturing; Powder Metallurgy; Materials Characterization; Energy-, Bio- and Nano Materials. The department offers B.Tech., M.S. (by Research) and Ph.D. Programmes (Full Time/Part Time).

List of Programs offered by the Department:

Program	Title of the Program
B.Tech.	Metallurgical and Materials Engineering
MS (by research)	Materials Technology
Ph.D.	Metallurgical and Materials Engineering

Note: Refer to the Rules and Regulations for B.Tech. program (weblink) given on the institute website.

Programme Educational Objectives (PEOs) for the B.Tech. (DMME) Programme:

Within few years after the end of the B.Tech. in Metallurgical and Materials Engineering programme, graduates will be able to:

PEO1	Apply knowledge of basic sciences, metallurgical and materials engineering for the development of materials through extraction, refining, processing and manufacturing .
PEO2	Model, design, process, characterize and evaluate materials for generic, industrial and strategic applications .
PEO3	Work effectively as an individual and in a team in inter- and multi-disciplinary projects with ethics and professionalism
PEO4	Pursue life-long learning to enhance knowledge and professional skills for career growth with social and environmental responsibility

Programme Articulation Matrix (PEO vs. Mission) for the B.Tech. (DMME) Programme:

PEO\Mission	M1	M2	M3	M4
PEO1	S	M	S	M
PEO2	S	S	M	M
PEO3	M	S	S	M
PEO4	S	M	S	M

S: Strong correlation, M: Medium correlation, L: Low correlation

B.Tech. – Metallurgical and Materials ENGINEERING
Program Outcomes (POs)

At the end of the program, the student will be able to:

PO1	**Engineering knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
PO2	**Problem analysis**: Identify, formulate, research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
PO3	**Design/Development of solutions**: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
PO4	**Conduct investigations of complex problems**: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
PO5	**Modern tool usage**: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modelling to complex engineering activities with an understanding of the limitations.
PO6	**The engineer and society**: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
PO7	**Environment and sustainability**: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
PO8	**Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
PO9	**Individual and team work**: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
PO10	**Communication**: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
PO11	**Project management and Finance**: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in

	multidisciplinary environments.
PO12	**Life-long learning**: Recognize the need for and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Program Specific Outcomes (PSOs):

PSO1	Select/design processes for extraction and manufacturing of ferrous and non-ferrous metals and alloys.
PSO2	Apply thermodynamic, physical and mechanical metallurgy principles to improve the performance and service life of the components.
PSO3	Process and develop ceramic, polymer, composites and functional materials for specific applications.
PSO4	Evaluate and assess structure and properties of materials using characterization techniques.

Degree Requirements for B.Tech. (DMME) Programme

	Proposed Credits (New regulation)
Basic Science Core (BSC)	19 (11.7%)
Engineering Science Core (ESC)	22 (13.58%)
Humanities and Social Science Core (HSC)	06 (3.7%)
Program Core Courses (PCC)	63 (38.88%)
Departmental Elective Courses (DEC)	15 (9.25%)
Open Elective Courses (OPC)	09 (5.55%)
Program Major Project (PRC)/Skill Development (SD)/Foreign Languages	22 (13.58%)
EAA: Games and Sports (MSC)	2 (1.2%)
MOOCs (MOE)	4 (2.46%)
Total	162

Choice Based Credit System: 26.54 %

NOTE: The minimum no. of credits required to award B.Tech. degree is 162 as per the proposed curriculum.

Credit Distribution in Each Semester										
	I	II	III	IV	V	VI	VII	VIII	TOT	REQ
BSC	8	8	0	3	0	0	0	0	19	≥ 19
ESC	4	10	4	4	0	0	0	0	22	≥ 14
HSC	3	0	0	0	0	3	0	0	6	≥ 06
PCC	0	0	16	13	16	8	10	0	63	≥ 62
DEC	0	0	0	0	0	6	6	3	15	≥ 15
OPC	0	0	0	0	3	3	0	3	9	≥ 09
PRC/ SD	5	2	0	2	0	3	4	6	22	≥ 15
EAA (MSC)	1	1	0	0	0	0	0	0	2	≥ 2
MOOCS (MOE)	0	0	0	0	2	0	0	2	4	≥ 4
	21	21	20	22	21	23	20	14	162	

Scheme of Instruction
B.Tech. (Metallurgical and Materials Engineering) Course Structure

I – Year: I/II – Semester (Physics Cycle)

PHYSICS CYCLE							
S. No.	**Course Code**	**Course Title**	**L**	**T**	**P**	**Credits**	**Cat. Code**
1	MA101/ MA151	Differential and Integral Calculus / Matrices and Differential Equations	3	0	0	**03**	**BSC**
2	HS101	English for Technical Communication	2	0	2	**03**	**HSC**
3	PH101	Engineering Physics	3	0	0	**03**	**BSC**
4	EC101	Basic Electronic Engineering	2	0	0	**02**	**ESC**
5	CE102	Environmental Science and Engineering	2	0	0	**02**	**ESC**
6	CS101	Introduction to Algorithmic Thinking and Programming	3	0	0	**03**	**SD**
7	CS102	Introduction to Algorithmic Thinking and Programming Lab	0	1	2	**02**	**SD**
8	PH102	Engineering Physics Lab	0	1	2	**02**	**BSC**
9	EA101/ EA151	Physical Education/Health Education	0	0	3	**01**	**MSC**
		Total	**15**	**2**	**9**	**21**	

I – Year: I/II – Semester (Chemistry Cycle)

CHEMISTRY CYCLE							
S. No	**Course Code**	**Course Title**	**L**	**T**	**P**	**Credits**	**Cat. Code**
1	MA101/ MA151	Differential and Integral Calculus / Matrices and Differential Equations	3	0	0	**03**	**BSC**
2	ME102	Engineering Graphics with Computer Aided Drafting	0	1	2	**02**	**ESC**
3	CY101	Engineering Chemistry	3	0	0	**03**	**BSC**
4	EE101	Elements of Electrical Engineering	2	0	0	**02**	**ESC**
5	BT101	Biology for Engineers	2	0	0	**02**	**ESC**
6	ME101	Basics of Mechanical Engineering	2	0	0	**02**	**ESC**
7	CE101	Engineering Mechanics	2	0	0	**02**	**ESC**
8	ME103	Workshop Practice	0	1	2	**02**	**SD**
9	CY102	Engineering Chemistry Lab	0	1	2	**02**	**BSC**
10	EA101/ EA151	Physical Education/Health Education	0	0	3	**01**	**MSC**
		TOTAL	**14**	**3**	**9**	**21**	

Note:

BSC: Basic Science Core

ESC: Engineering Science Core

HSC: Humanities and Social Science Core

PCC: Program Core Courses

DEC: Departmental Elective Courses

OPC: Open Elective Courses

Program Major Project (PRC)/Skill Development (SD)/Foreign Languages

EAA (MSC): Games and Sports

MOOCs (MOE)

SCHEME OF INSTRUCTION
B.Tech. (Metallurgical and Materials Engineering) Course Structure

Summer Internship – I#

II – Year: I – Semester

S.No	Course Code	Course Title	L	T	P	Credits	Cat. Code
1	ME235	Strength of Materials	3	1	0	**04**	**ESC**
2	MM201	Physical Metallurgy	3	0	0	**03**	**PCC**
3	MM202	Principles of Extractive Metallurgy	3	0	0	**03**	**PCC**
4	MM203	Metallurgical Thermodynamics and Kinetics	3	0	0	**03**	**PCC**
5	MM204	Transport Phenomena	3	0	0	**03**	**PCC**
6	MM205	Physical Metallurgy and Metallography Laboratory	0	0	3	**02**	**PCC**
7	MM206	Extractive Metallurgy Laboratory	0	0	3	**02**	**PCC**
		TOTAL	**15**	**1**	**6**	**20**	

II – Year: II – Semester

S.No	Course Code	Course Title	L	T	P	Credits	Cat. Code
1	MA253	Transform Techniques and Numerical Methods	3	0	0	**03**	**BSC**
2	EE257	Numerical Simulations Using Python	2	1	2	**04**	**ESC**
3	MM251	Phase Transformation and Heat Treatment	3	1	0	**03**	**PCC**
4	MM252	Non-Ferrous Extractive Metallurgy	3	0	0	**03**	**PCC**
5	MM253	Casting and Solidification	3	0	0	**03**	**PCC**
6	MM254	Phase Transformation and Heat Treatment Laboratory	0	0	3	**02**	**PCC**
7	MM255	Casting and Solidification Laboratory	0	0	3	**02**	**PCC**
8	MM299	Mini Project – I (EPICS based)	0	0	4	**02**	**SD**
		TOTAL	**14**	**2**	**12**	**22**	

Summer Internship – II#

SCHEME OF INSTRUCTION
B.Tech. (Metallurgical and Materials Engineering) Course Structure

III – Year: I – Semester

S. No	Course Code	Course Title	L	T	P	Credits	Cat. Code
1	MM301	Iron and Steel Making	3	0	0	**03**	**PCC**
2	MM302	Mechanical Behavior of Materials	3	0	0	**03**	**PCC**
3	MM303	Powder Metallurgy	3	0	0	**03**	**PCC**
4	MM304	Metal Joining	3	0	0	**03**	**PCC**
5	MM305	Mechanical Behavior of Materials Laboratory	0	0	3	**02**	**PCC**
6	MM306	Powder Metallurgy Laboratory	0	0	3	**02**	**PCC**
7		Open Elective – 1/ Foreign language	3	0	0	**03**	**OPC/ SD**
8		MOOCS-1	2	0	0	**02**	**MOE**
		TOTAL	**17**	**0**	**6**	**21**	

III – Year: II – Semester

S. No	Course Code	Course Title	L	T	P	Credits	Cat. Code
1	MM351	Corrosion Engineering	3	0	0	**03**	**PCC**
2	MM352	Metal Forming	3	0	0	**03**	**PCC**
3		Department Elective – 1	3	0	0	**03**	**DEC**
4		Department Elective – 2	3	0	0	**03**	**DEC**
5	SM355	Engineering Economics and Management	3	0	0	**03**	**HSC**
6	MM353	Corrosion Engineering Lab	0	0	3	**02**	**PCC**
7		Open Elective – 2/ Foreign language elective	3	0	0	**03**	**OPC/ SD**
8	MM399	Mini Project - II	0	0	6	**03**	**SD**
		TOTAL	**18**	**0**	**9**	**23**	

Summer Internship – III#

#: The student can do Summer Internship with duration of minimum 45 days at Institutes / Organizations / Industries and produce the certificate of completion and copy of internship report to the department.

It is optional only, Not Mandatory.

SCHEME OF INSTRUCTION
B.Tech. (Metallurgical and Materials Engineering) Course Structure

IV – Year: I – Semester

S.No	Course Code	Course Title	L	T	P	Credits	Cat. Code
1	MM401	Materials Characterization	3	0	0	**03**	**PCC**
2		Department Elective – 3	3	0	0	**03**	**DEC**
3		Department Elective – 4	3	0	0	**03**	**DEC**
4	MM402	Computational Materials Engineering	3	0	0	**03**	**PCC**
5	MM403	Materials for Automotive & Aerospace Applications**	2	0	0	**02**	**PCC**
6	MM404	Materials Characterization Lab	0	0	3	**02**	**PCC**
7	MM449	Project-Work Part - A	0	0	8	**04**	**PRC**
		TOTAL	**14**	**0**	**11**	**20**	

** The PCC Subject may be offered with the support of Industry.

IV – Year: II – Semester

S.No	Course Code	Course Title	L	T	P	Credits	Cat. Code
1		Department Elective – 5*	3	0	0	**03**	**DEC**
2		Open Elective – 3*	3	0	0	**03**	**OPC**
3		MOOCS-2	2	0	0	**02**	**MOE**
4	MM499	Project-Work Part – B (with option of Industrial Training /Internship)	0	0	12	**06**	**PRC**
		TOTAL	**8**	**0**	**12**	**14**	

*If the students are in Industrial training, the electives may be conducted online.

Professional Elective Courses:

Semester	Elective Number	Course Code	Elective name
VI	DE -I	MM361	Theory of Metallurgical Processes
VI	DE -I	MM362	Fuels and Refractories
VI	DE -I	MM363	Mineral Processing
VI	DE -II	MM364	Surface Engineering
VI	DE -II	MM365	Advanced Manufacturing Processes
VI	DE -II	MM366	Metallurgical waste recycling
VII	DE -III	MM411	Metallurgical Failure Analysis
VII	DE -III	MM412	Non-Destructive Testing
VII	DE -III	MM413	Materials selection and design
VII	DE -IV	MM414	Ceramics, Polymers, and Composites
VII	DE -IV	MM415	Energy and Nuclear Materials
VII	DE -IV	MM416	Smart Materials
VIII	DE -V	MM461	Electronic and Magnetic Materials
VIII	DE -V	MM462	Thin Films and Coatings
VIII	DE -V	MM463	Introduction to Nano Science and Technology

Open Elective Courses (offered to other departments):

Semester	Elective Number	Course Code	Elective name
V	OP- I	MM340	Introduction to Materials Science and Engineering
VI	OP – II	MM390	Fundamentals of Materials Processing Technology
VIII	OP – III	MM490	Materials Testing & Analysis

Certificate course in relevant discipline: Courses of extra 12 credits are required to be identified by each department. Some of these courses may be DAC approved MOOCs courses.

The Courses designed for this program are:

Courses for Certificate Program							
S.No	**Course Code**	**Course Title**	**L**	**T**	**P**	**Credits**	**Cat. Code**
1	MMC201	Physical Metallurgy	3	0	0	**03**	**PCC**
2	MMC202	Principles of Extractive Metallurgy	3	0	0	**03**	**PCC**
3	MMC203	Metallurgical Thermodynamics and Kinetics	3	0	0	**03**	**PCC**
4	MMC254	Casting and Solidification	3	0	0	**03**	**PCC**
		TOTAL	**12**	**0**	**0**	**12**	

Diploma: Courses of additional 20 credits are required to be identified by each department for offering to Diploma students to meet the requirement of additional 20 credits including project component.

Courses for Diploma Program							
S.No	**Course Code**	**Course Title**	**L**	**T**	**P**	**Credits**	**Cat. Code**
1	MMD301	Iron and Steel Making	3	0	0	**03**	**PCC**
2	MMD302	Mechanical Behavior of Materials	3	0	0	**03**	**PCC**
4	MMD304	Metal Joining	3	0	0	**03**	**PCC**
5		MOOCS-1	4	0	0	**04**	**MDC**
6		MOOCS-2	4	0	0	**04**	**MDC**
7	MMD399	Mini Project - II	0	0	6	**03**	**SD**
8							
		TOTAL	**17**	**0**	**6**	**20**	

Minors: Each department should identify list of courses for the minor degree. These identified courses will be offered to the minor degree students as mentioned below.

Courses for Minor

S. No	Course Code	Course Title	L	T	P	Credits	Offered semester
1	MMM251	Elements of Materials Engineering	3	0	0	**03**	**4th**
2	MMM301	Powder Processing Technology	3	0	0	**03**	**5th**
3	MMM351	Testing and Evaluation of Materials	3	0	0	**03**	**6th**
4	MMM401	Environmental Degradation of Materials	3	0	0	**03**	**7th**
5	MMM302	Powder Processing Technology Laboratory	0	0	3	**02**	**4th/5th**
6	MMM352	Testing and Evaluation of Materials Laboratory	0	0	3	**02**	**6th/7th**
		TOTAL				**16**	

Honors:

Courses for Honors

S.No	Course Code	Course Title	L	T	P	Credits	Offered semester
1	MMH301	Advances in Iron and Steel Making	3	1	0	**04**	**5th**
2	MMH302	X-Ray Diffraction	3	1	0	**04**	**5th**
3	MMH351	High Temperature Materials	3	1	0	**04**	**6th**
4	MMH352	Electron Microscopy	3	1	0	**04**	**6th**
5	MMH401	Special Steels and Alloys	3	1	0	**04**	**7th**
		TOTAL				**20**	

Note:

1. A student is permitted to do either Minor or Honors only, but not both.
2. A student is permitted to do only one minor/ one honors.

Detailed Syllabus
I Year B.Tech. Course Structure
(Common for All Branches)

MA101	**Differential and Integral Calculus** **I B.Tech. I Semester - all sections**	**BSC**	**3-0-0**	**3 Credits**

Pre-requisites: None

Syllabus:

Differential Calculus of functions of several variable: Review of Limit, continuity (sequential verification) and differentiability, Partial differentiation; Total differentiation; Euler's theorem and generalization; Change of variables- Jacobians; Maxima and minima of functions of several variables (2 and 3 variables); Lagrange's method of multipliers. (14)

Integral Calculus: Convergence of improper integrals; Beta and Gamma integrals; Differentiation under integral sign; Double and Triple integrals - computation of surface areas and volumes; change of variables in double and triple integrals. (14)

Vector Calculus: Scalar and vector fields; vector differentiation; level surfaces; directional derivative; gradient of a scalar field; divergence and curl of a vector field; Laplacian; Line and Surface integrals; Green's theorem in a plane; Stokes' theorem; Gauss Divergence theorem. (14)

Reference Books:

1. Joel R. Hass, Maurice D. Weir, George B. Thomas, Thomas' Calculus, 12th edition, Pearson, 2010.
2. Erwin Kreyszig, *"Advanced Engineering Mathematics"*, Eighth Edition, John Wiley and Sons, 2015
3. B. S. Grewal, *"Higher Engineering Mathematics"*, Khanna Publications, 2015
4. R. K. Jain and S. R. K. Iyengar, *"Advanced Engineering Mathematics"*, Fifth Edition, Narosa Publishing House, 2016.
5. T. M. Apostol, Calculus, Volumes 1 and 2 (2nd Edition), Wiley Eastern, 1980.

MA151	**Matrices and Differential Equations** I B.Tech. II Semester - all sections	**BSC**	**3-0-0**	**3 Credits**

Pre-requisites: Mathematics-I
Syllabus:

Matrix Theory: Linear dependence and independence of vectors; Rank of a matrix; Consistency of the system of linear equations; Eigenvalues and eigenvectors of a matrix; Caley-Hamilton theorem and its applications; Reduction to diagonal form; Reduction of a quadratic form to canonical form - orthogonal transformation; Properties of complex matrices - Hermitian, skew-Hermitian and Unitary matrices. (14)

Ordinary Differential Equations of Higher Order: Higher order linear differential equations with constant coefficients - homogeneous and non-homogeneous; Euler and Cauchy's differential equations; Method of variation of parameters; System of linear differential equations; applications in physical problems - forced oscillations, electric circuits, etc. (14)

Laplace Transforms: Laplace transforms; inverse Laplace transforms; Properties of Laplace transforms; Laplace transforms of unit step function, impulse function, periodic function; Convolution theorem, Solving certain initial value problems, Solving system of linear differential equations, Finding responses of systems to various inputs viz. sinusoidal inputs acting over a time interval, rectangular waves, impulses etc. (14)

Reference Books:

1. E. Kreyszig, Advanced Engineering Mathematics, Eighth Edition, John Wiley and Sons, 2015.
2. B. S. Grewal, Higher Engineering Mathematics, Khanna Publications, 2015.
3. R. K. Jain and S. R. K. Iyengar, Advanced Engineering Mathematics, Fifth Edition, Narosa Publishing House, 2016.
4. G. Strang, Linear Algebra and Its Applications, 4th Edition, Brooks/Cole India, 2006.
5. T. M. Apostol, Calculus, Volume 2 (2nd Edition), Wiley Eastern, 1980.

HS101	ENGLISH FOR TECHNICAL COMMUNICATION	SD	2 – 0 – 2	3 Credits

Pre-requisites: None.

Syllabus:

Grammar Principles and Vocabulary Building: -Exposure to basics of grammar- tenses—active and passive voice- their usage-Concord -Error Detection-Idioms and Phrases-Phrasal verbs—their meanings and usage, Synonyms and antonyms

Developing paragraphs using mind mapping- Definition- structure- Types and Composition- unity of theme- coherence- organization patterns-essays and their structure-note-making

Letter Writing: Formal letters-- communicative purpose-strategy- letter format and mechanics- letters of request, complaint and invitation-writing emails
Reading Comprehension –skimming-scanning-intensive and extensive reading-reading to retrieve information ––techniques of comprehension -find clues to locate important points-answering objective type questions–inference, elimination

Delegation- steps involved in delegation-preparing delegation for a program
Preparing Questionnaire-Determine audience and content of each question-response structure-develop wording for each question-establish sequence of questions

Profiling Readers-Audience analysis- Identifying potential audience- Identifying primary, secondary, tertiary readers, and gatekeepers- Identifying the needs, values, and attitude of the readers
Resume Writing-Writing for Professional Networking-Academic writing-research proposals-Interpretation of Graphs.

Technical Report-Writing - kinds of reports-proposals, progress and final reports- their structure-features- process of writing a report-editing.

Language Laboratory
Introduction to basic phonetics: Vowels, Consonants, Diphthongs, phonetic symbols
Listening: Challenges in listening, enhancing listening skills, listening activities
Speaking: JAM using cue cards-role play-Group presentation-presentation with emphasis on body language- public speaking-extempore speech
Group discussion: Dos and don’ts, intensive practice
Mock interview: Interview etiquette, common interview questions

Text Books:

1. Emden, Joan van. *Effective Communication for Science and Technology*. Macmillan Education UK, 2001.
2. Mohan, Krishna and Meera Banerji. *Developing Communication Skills*. Macmillan
3. India Limited, 2000.
4. Murphy, Raymond. Intermediate English Grammar. Cambridge University Press, 2014.
5. Narayanaswami, V. R. Strengthen Your Writing. Orient Longman Private Limited, 2005.
6. Soundaraj, Francis. Speaking and Writing for Effective Business Communication.

Macmillan Publishers India Limited, 2007.
7. Ur, Penny. Discussions that Work. Cambridge University Press, 1981.

Reference Books

1. Aarts, Bas. Oxford Modern English Grammar. Oxford University Press, 2011.
2. Anderson, Marilyn, Pramod K. Nayar, and Madhucchanda Sen. Critical Thinking, Academic Writing and Presentation Skills. Pearson Education, 2008.
3. Blake,Gary.The Elements of Technical Writing. Pearson,2000
4. Brown, Carla L. Essential Delegation Skills. Routledge, 2017.
5. Busan, Tony. Mind Map Mastery. Walkins, 2018.
6. Carlisle, Joanne and Melinda S. Rice. Improving Reading Comprehension Research-based Principles and Practices. York Press, 2002.
7. Carter, Ronald and Michael McCarthy. Cambridge Grammar of English: A Comprehensive Guide. Cambridge University Press, 2006.
8. Carter, Ronald, Rebecca Hughes, and Michael McCarthy. Exploring Grammar in Context: Upper-intermediate and Advanced. Cambridge University Press, 2000.
9. Eastwood, John. Oxford Guide to English Grammar. Oxford University Press, 1994.
10. Harris, David.F. Complete Guide to Writing Questionnaires. I& M Press, 2014.
11. Hering, Lutz and Heike Hering. How to Write Technical Reports: Understandable Structure, Good Design, Convincing Presentation. Springer; 2010.
12. HuckinN.Thomas and Leslie A.OlsenTechnical Writing and Professional Communication for Non-native Speakers. McGraw-Hill Education,1991.
13. Laplante, Phillip A. Technical Writing: A Practical Guide for Engineers, Scientists, and Nontechnical Professionals. CRC Press, 2018.
14. McQuail, Dennis. Audience Analysis. Sage, 1997
15. Ogden, Richard. Introduction to English Phonetics. Edinburgh University Press, 2017.
16. Parker, Glenn M. Team Players and Teamwork: New Strategies for Developing Successful Collaboration. Wiley, 2011.
17. Seely, John. Oxford Guide to Effective Writing and Speaking: How to Communicate Clearly. Oxford University Press: 2013.

PH101	Engineering Physics	BSC	3-0-0	3 Credits

Syllabus:

Waves and Optics

Interference: Superposition principle, coherence of light, methods to produce coherent light: division of amplitude and wave front division, Young's double slit experiment: concept, working principle, and applications, Newton's ring: concept, working principle, and applications

Diffraction: Fraunhofer's single-slit diffraction, diffraction grating, and resolving power of a grating.

Polarization: Types of optical polarization, various methods to produce polarized light, working and applications of retarder plates, and half-shade polarimeter: construction and working principle.

Lasers and Optical Communication

LASER: Basic theory of LASER, Einstein's coefficients and their relations, concept of population inversion, components of lasers, modes of laser beam, construction and working principle of various types of lasers: Ruby, Helium-Neon, and semiconductor diode lasers.

Optical Fibre: Optical fibre and its working principle, total internal reflection, numerical aperture, modes of propagation, and classification of optical fibres.

Quantum Physics

Origin of quantum theory and related experiments: Black-Body radiation, photo-electric effect, and Compton effect. Heisenberg's uncertainty principle, de- Broglie's wave concept, phase and group velocities, wave function, and its properties, operators, Schrödinger's time-dependent and time-independent equations, particle in one-dimensional, infinite potential and finite potential wells, and quantum tunneling phenomena and their applications in alpha decay, and scanning tunneling microscopy (STM).

Magnetic, Superconducting and Dielectric Materials

Magnetic Materials: Introduction to Weiss theory of ferromagnetism, concepts of magnetic domains, Curie transition, hard and soft magnetic materials and their applications, magneto-resistance, GMR, and TMR.

Superconducting Materials: Introduction to superconductivity, Meissner effect, Type-I and Type-II superconductors and their applications.

Dielectric Materials: Introduction to dielectrics, dielectric constant, polarizability, frequency and temperature dependent polarization mechanism in dielectrics, dielectric loss, and applications.

Advanced Functional Materials & NDT

Smart Materials: Biomaterials, high-temperature materials and smart materials, applications of functional materials.

Nanomaterials: Introduction, classification, and properties of nanomaterials, various methods of synthesizing nanomaterials: top-down (ball milling) and bottom-up (sol-gel) approaches.

Photovoltaic Materials: Solar spectrum, photovoltaic effect, materials, structure and working principle, I-V characteristics, power conversion efficiency, quantum efficiency, emerging PV technologies, and applications.

NDT: Methods of non-destructive testing

Reference Books

1. A Textbook of Engineering Physics, M. N. Avadhanulu, P. G. Kshirsagar, S. Chand and Company (2015).
2. Concepts of Modern Physics, Beiser A., Mc. Graw Hill Publishers (2003).
3. Optics, Ajoy Ghatak, Tata Mc Graw Hill (2012).
4. Materials Science and Engineering: An Introduction (Tenth edition), William D. Callister, John Wiley & Sons (2018).
5. Introduction to Solid State Physics, Charles Kittel, Wiley Publishers (2011).

EC101	Basic Electronic Engineering	ESC	2 – 0 – 0	2 Credits

Syllabus:

Introduction to electronics systems, diode circuit models and applications, Zener diode as regulator, photodiode.

Transistor and applications: Introduction to transistors, BJT Characteristics, biasing and applications. FET and MOSFET characteristics and applications.

Feedback in Electronic Systems: open loop and closed loop systems, Negative and positive Feedback, Principles of LC and RC oscillators.

Integrated Circuits: Operational amplifiers Characteristics and applications, linear operations using Op-amps.

Digital Circuits: Number systems and logic gates, Combinational Logic circuits, Sequential Circuits, Analog to Digital and Digital to Analog converters (ADC/DAC).

Laboratory measuring instruments: principles of digital multi-meters, Cathode ray oscilloscopes (CRO).

Reference Books

1. Bhargava N. N., D C Kulshreshtha and S C Gupta, Basic Electronics & Linear Circuits, 2nd Edition, Tata McGraw Hill, 2013.
2. S. Sedra and K. C. Smith, Microelectronic Circuits, Oxford University Press , 6th Edition
3. Leach , Malvino, Saha, Digital Principles and Applications, McGraw Hill Education , 8th Edition
4. Boylestad, Robert L., Louis Nashelsky, Electronic Devices and Circuit, Pearson , 11th Edition
5. Helfrick and Cooper, ― Modern Electronic Instrumentation and Measurement Techniques‖ PHI, 2011
6. Neil Storey, Electronics A Systems Approach, 4th Edition, Pearson Education Publishing Company Pvt Ltd.

CE102	ENVIRONMENTAL SCIENCE AND ENGINEERING	ESC	2-0-0	2 Credits

Syllabus

Introduction to Environmental Science: Environment and Societal Problems, Major - Environmental Issues, Global Climate Change Agreements, Montreal, Kyoto Protocol & Paris Agreement, Basics of Environmental Impact Assessment, Principles of Sustainability, and related indices, Population Dynamics, Urbanization. Identification and Evaluation of Emerging Environmental Issues with Air, Water, Wastewater and Solid Wastes, Introduction to Environmental Forensics.

Water & Wastewater Treatment: Water Sources, constituents, potable water quality requirements (IS 10500), overview of water treatment, sources and types of pollutants, their effects, self-purification capacity of water bodies, principles of wastewater treatment, 5R Concept.

Air & Noise Pollution: Sources, classification and their effects, national ambient air quality standards (NAAQS), air quality index, dispersion of pollutants, control of air pollution, understanding and improving indoor air quality, sources of noise pollution, effects, quantification of noise pollution.

Solid Waste Management: Sources and characteristics of solid waste, effects, 3R concept, sustainable practices in waste management, CPHEEO guidelines for solid waste management, transition to zero waste lifestyle.

Text Books:

1. G.B. Masters, Introduction to Environmental Engineering and Science, Pearson Education, 2013.
2. Gerard Kiely, Environmental Engineering, McGraw Hill Education Pvt Ltd, Special Indian Edition, 2007.
3. Benny Joseph, Environmental Science and Engineering, Tata McGraw-Hill, New Delhi, 2006.

Reference Books:

1. Peavy, H.S, Rowe, D.R., and G. Tchobanoglous (1985), Environmental Engineering, McGraw Hill Inc., New York
2. W P Cunningham, M A Cunningham, Principles of Environmental Science, Inquiry and Applications, Tata McGraw Hill, Eighth Edition, 2016.

CS101	Introduction to Algorithmic Thinking and Programming	SD	3 – 0 – 0	3 Credits

Pre-requisites: None

Course Outcomes: At the end of the course, the student will be able to:

CO1	Construct algorithms for solving problems that requires solutions involving searching, sorting, selection and / or a numerical method as a sub-routine.
CO2	Analyze the suitability of different algorithmic design paradigms for solving problems with an understanding of the time and space complexities incurred.
CO3	Construct algorithms for solving problems with an understanding of the internals of a computing system and its components like processor, memory and I/O sub-systems.
CO4	Construct efficient modular programs for implementing algorithms by leveraging suitable control structures.
CO5	Construct efficient programs by selecting and using suitable in-built Data Structures and programming language features available.

Course Articulation Matrix:

PO / CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	S	M	L									
CO2	S	M	L									
CO3	S	M	L		L							
CO4	S	M	L		S							
CO5	S	M	L		S							

S: Strong correlation, M: Medium correlation, L: Low correlation

Syllabus:

Fundamentals of Computers, Historical perspective, Early computers, Modern Computers, Hardware Components of a Computer, Data Representation in Computers, Introduction to Operating Systems, Software and Firmware, Problems, Flowcharts, Memory, Variables, Values, Instructions, Programs.

Problem solving techniques – Algorithmic approach, characteristics of algorithms, Problem solving strategies: Top-down approach, Bottom-up approach, Time and space complexities of algorithms, Algorithm Analysis.

Basic Syntax in Python, Data Types, Variables, Assignments, immutable variables, Types of Operators, Expressions, CoDMMEnts, Boolean Logic, Logical Operators in Python.

Conditional statements - If-else, Loops - while, for, Lazy Evaluation

Inbuilt Data Structures and their operations in Python: List, Tuples and Dictionaries.

Fundamental Algorithms: Swapping variables, Problems involving summation of a series, Sine function computation, Base Conversion, generation of sequences like Fibonacci, Reversing the digits of an integer, Character to number conversion.

Factoring Methods: Finding the square root, Finding the smallest divisor of an integer, finding the greatest common divisor using Euclid's algorithm, Computing the prime factors of an integer, generating prime numbers, Raising a number to a large power, Computation of the nth Fibonacci number.

Functions – Modular programming and benefits, user defined functions, library functions, parameter passing, Formal and Actual arguments, named arguments return values, Recursion.

Sorting algorithms: Bubble, Selection and Insertion sorts, Search algorithms: Linear and binary search

String processing: Algorithms for implementing String functions like Strlen, Strcpy, StrRev, Strcmp, Searching for a keyword or pattern in a text.

File and Directory Handling: Reading and Writing to/from a file, Formatted File creation and operations.

Simple 2D Graphics, drawing 2D objects using Turtle Graphics.

Text Books:

1. Kenneth Lambert, Fundamentals of Python: First Programs, Cengage Learning, 2019
2. R.G. Dromey, how to solve it by Computer, Pearson, 2008.

CS102	Introduction to Algorithmic Thinking and Programming Lab	SD	0 – 1 – 2	2 Credits

Pre-requisites: None

Course Outcomes: At the end of the course, the student will be able to:

CO1	Construct, debug, test and run efficient programs by leveraging suitable flow of control constructs and syntactic units of the programming language.
CO2	Construct efficient programs by constructing and translating algorithms for solving problems using sorting, searching, selection and / or arithmetic computations.
CO3	Implement, refactor, test and debug functional programs in a shell-based run time environment.
CO4	Construct efficient programs by demonstrating problem-solving skills and out-of-the-box algorithmic thinking.

Course Articulation Matrix:

PO / CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO1	S	M	L		S				M			L
CO2	S	M	L		S				M			L
CO3	S	M	L		S				M			L
CO4	S	M	L		S				M			L

S: Strong correlation, M: Medium correlation, L: Low correlation

Syllabus:

List of Experiments:

1. Familiarization with Python installation, basic syntax and running scripts in the shell.
2. Programs on conditional control constructs.
3. Programs on iterative constructs. (While, do-while, for).
4. Programs using user defined functions and in-built function calls.
5. Programs related to Recursion.
6. Programs involving in-built data structures like List, Tuples and Dictionaries.
7. Programs related to String processing.
8. Programs related to Files and I/O.
9. Implementation of Factoring methods.
10. Programs that require sorting, searching and selection as sub-routines.
11. Problems involving simple 2D graphics.

12. Implementation of a capstone application to unify the concepts learnt in the course.

Text Books:

1. Kenneth Lambert, Fundamentals of Python: First Programs, Cengage Learning, 2019.
2. R.G. Dromey, how to solve it by Computer, Pearson, 2008.
3. The Python Tutorial, Available at: https://docs.python.org/3/tutorial/.

PH102	Engineering Physics Lab	BSC	0-0-2	2 Credits

List of experiments (any eight of the following):
Exposure to virtual lab (any three of the following):

S. No	Name of the experiment
1	Determination of Planck's constant using light emitting diode.
2	Determination of wavelength of monochromatic light in Newton's ring experiment.
3	Determination of the width of narrow slit by diffraction method.
4	Determination of wavelength of He-Ne laser using diffraction by a metal scale.
5	Determination of capacitance and time constant of a capacitor using R-C circuit.
6	Determination of wavelength of mercury spectrum by normal incidence method (diffraction grating).
7	Determination of specific rotation of an optically active material-using Laurent's half-shade polarimeter.
8	Determination of resonating frequency and bandwidth of an LCR circuit.
9	Determination of dielectric constant of various dielectric materials.
10	Studying B-H curve loop and permeability of magnetic materials.
11	Measuring spatial distribution of magnetic field between a pair of identical coils using Helmholtz coils.
12	Studying current-voltage characteristics of a photovoltaic material using solar cell.
13	Determination of numerical aperture of an optical fibre.
14	Determination of resistivities of various materials using four-probe method.

1. LCR – Series/Parallel
2. B-H Loop tracer
3. Planck's Constant
4. Numerical aperture of Optical Fiber
5. Newton's rings

Micro project:

This can be implemented in the subsequent semesters based on the facilities available. In the case of implementation, three or four experiments from the above listed eight experiments will be replaced with the project (~40 % of the experiments will be relaxed).

Reference Books:

1. Physics Laboratory Manual, School of Sciences (Physics), National Institute of Technology Andhra Pradesh (2020).
2. Practical Physics (Electricity, Magnetism, and Electronics), R. K. Shukla, A Srivastava, New age international publishers (2011).
3. B.Sc. Practical Physics, C. L. Arora, S. Chand & Co. Ltd. (2012).

EA101	Physical Education	MSC	0-0-3	1 Credit

Syllabus:

I. Introduction to Physical Education & EAA = Sports and Games

Meaning & Definition of Physical Education, Aims & Objectives of Physical Education, Importance of Physical Education

II. Physical Fitness & Wellness Lifestyle

Meaning & Importance of Physical Fitness, Components of Physical Fitness (Cardiovascular Endurance, Strength Endurance Muscular Endurance, Flexibility, Body Composition), Components of Motor Fitness (Agility, Balance, Power, Speed, Coordination), Development of Fitness Components

III. Training Methods in Physical Education

Circuit Training (Circuit Training), Continues Training (Endurance), Interval Training (Speed & Endurance), Fartlek Training (Speed Endurance), Weight Training (Maximum Strength), Plyometric Training (Power), Flexibility Training

IV. Test & Measurements

Measurements: Height, Weight, Age, Calculation of BMI, Motor Fitness and Physical Fitness Tests (Pre - Test & Post-Test), Cardiovascular Endurance - 9/12 Minute Run or Walk, Muscular Endurance – Sit Ups for abdominal strength, Strength Endurance – Flexed arm hang for girls / Pull ups for boys, (Speed – 50m Dash or 30mts Fly Start, Strength – Broad Jump, Vertical Jump for Lower Body, Medicine Ball Put for Shoulder Strength, Endurance - 800mts, Flexibility - Bend and Reach, Agility (Coordination)) – Shuttle Run and Box Run

V. Formal Activities

Calisthenics (free hand exercises), Dumbbells, Woops, Wands, Laziums (Rhythmic activities), Aerobic Dance and Marching

VI. Sports / Games

Following sub topics related to any one Game/Sport of choice of student out of: Athletics, Badminton, ball badminton, Kabaddi, Kho-Kho, Table Tennis, Yoga etc., Teaching & Coaching of the Game/Sport, Latest General Rules of the Game/Sport.

Specifications of Play Grounds and Related Sports Equipment

EA151	Health Education	MSC	0-0-3	1 Credit

Health Education & Personal Hygiene
Introduction & Meaning of Health Education, Definition of Health Education, Principles of Health Education, Importance of Health Education, Meaning of Personal Hygiene, Importance of Personal Hygiene, Personal cleanliness (teeth, ears, eyes, nose & throat, nails & fingers, skin, cloths, and hair).

Nutrition
Introduction of Nutrition, Balanced Diet, Daily Energy Requirements, Nutrient Balance, Nutritional Intake, Eating and Competition, Ideal Weight

First Aid & Injury Management
Introduction, Types and Principles of First Aid, Functions of First Aider, Reasons for Sports Injuries,The First Aid and Emergency Treatment in Various cases (drowning, dislocation & fractures, burns, electric shock, animal bite, snake bite, poison, etc.

Human Posture
Introduction, Meaning of Posture, types of Good Posture, causes of Poor Posture, preventive and Remedial Poor Posture, common Postural Deformities, Body Types, Advantages of Good Posture

Yoga
Introduction, Meaning & Importance of Yoga, Elements of Yoga, Introduction - Asanas, Pranayama, Meditation & Yogic Kriyas, Yoga for concentration & related Asanas (standing asanas, sitting asanas, supine and prone postures.), Relaxation Techniques for improving concentration – Yoga – nidra, Pranayama

Sports / Games
Following sub topics related to any one Game/Sport of choice of student out of: Athletics, Badminton, ball badminton, Kabaddi, Kho-Kho, Table Tennis, Yoga etc.,Teaching & Coaching of the Game/Sport., Latest General Rules of the Game/Sport, Specifications of Play Grounds and Related Sports Equipment.

ME102	Engineering Graphics with Computer Aided Drafting	ESC	2-0-0	2 Credits

Note: 50% of the Practice through manual drawing and 50% of the Practice through a Computer Aided Drafting Package.

Syllabus:

Introduction: Overview of the course, Lines Lettering and Dimensioning: Types of lines, Lettering, Dimensioning, Geometrical Construction of Polygons, Scales. Introduction to Computer Aided Drafting (CAD), DRAW tools, MODIFY tools, TEXT, DIMENSION, PROPERTIES, etc.

Orthographic Projection: Principles, of Orthographic projection, Four Systems of Orthographic Projections.

Projection of Points: Projections of points when they are situated in different quadrants.

Projections of Lines: Projections of a line parallel to one of the reference planes and inclined to the other, line inclined to both the reference planes, Traces.

Projections of Planes: Projections of a plane perpendicular to one of the reference planes and inclined to the other, Oblique planes.

Projections of Solids: Projections of solids whose axis is parallel to one of the reference planes and inclined to the other, axis inclined to both the planes.

Sections of Solids: Sectional planes, Sectional views - Prism, pyramid, cylinder and cone, true shape of the section.

Isometric Views: Isometric axis, Isometric Planes, Isometric View, Isometric projection, Isometric views - simple objects.

Reference Books:

1. N.D. Bhatt and V.M. Panchal, Engineering Graphics, Charotar Publishers, 2013.
2. Sham Tickoo, AutoCAD 2017 for Engineers & Designers, Dreamtech Press, 23 rd Edition, 201

CY101	Engineering Chemistry	BSC	3-0-0	3 Credits

Syllabus:

Basic Organic Chemistry

Reaction intermediates: carbocations, carbanions, free radicals and carbenes. Classification of organic reactions, examples and their mechanisms: substitution, addition, elimination and rearrangement reactions. Reimer–Tiemann reaction, Kolbe-Schmidt reaction, Cannizzaro reaction. Pinacol-Pinacolone, Hofmann and Beckmann rearrangements. Diels-Alder reaction.

Spectroscopic Techniques for Chemical Analysis

Introduction of spectroscopy, Quantum aspects of electronic, vibrational and nuclear energy levels. UV-Visible spectroscopy: Principle, Instrumentation, Beer-Lambert's law, Effect of conjugation, Woodward-Fieser empirical rules for acyclic/cyclic dienes. IR spectroscopy: Principle, Factors that affect vibrational frequencies and functional group detection. Proton NMR spectroscopy: Principle, Instrumentation, Chemical equivalency, Chemical shift and spin-spin splitting. Applications of UV-Vis, IR and proton-NMR spectroscopy in determining the structure of small organic molecules.

Coordination Chemistry

Introduction of coordination chemistry, Valence bond (VB) theory and shapes of Inorganic Compounds, Spectrochemical series, Crystal Field theory (CFT): octahedral and tetrahedral complexes, Crystal field splitting energy (CFSE); Molecular Orbital (MO) Theory: Molecular orbital diagrams for octahedral complexes (strong and weak ligand fields).

Electrochemistry

Electrodes, Electrochemical Cells, Electrochemical series and Nernst equation; Conductometry and Potentiometry; Batteries: Types of batteries, Ni-Cd and Lithium (Li)-ion batteries; Fuel Cells: Hydrogen-Oxygen, Methanol-Oxygen fuel cells; Corrosion - Theories of corrosion, Wet corrosion, Types of wet corrosion, Factors affecting the rate of corrosion, Corrosion control methods: Sacrificial anode method and Impressed current method.

Engineering Materials and Applications

Polymers: Introduction, Types of polymerization, Functionality in polymers, Number and Weight average molecular weight, Polydispersity index, Biodegradable polymers; Conductive polymers: classification, examples and applications; Organic light emitting diode (OLED): structure, principle and applications; Optical fibres: principle and Applications.

Reference Books:

1. Organic Chemistry, Clayden, Greaves, Warren and Wothers, Oxford University Press, 2014.
2. Organic Spectroscopy, William Kemp, 2nd edition, Macmillan publishers, 2019.
3. Advanced Inorganic Chemistry, F. Albert Cotton, Geoffrey Wilkinson, Carlos A. Murillo and Manfred Bochmann, 6th Edition, 1988.
4. Physical Chemistry, P. Atkins and Julio de Paula, 8th Edition, Freeman & Co. 2017.
5. A Textbook of Engineering Chemistry, Shashi Chawla, 2017.
6. Polymer Science and Technology, Premamoy Ghosh, 3rd edition, McGraw-Hill, 2010.

EE101	Elements of Electrical Engineering	ESC	2-0-0	2 Credits

Syllabus:

Basic Concepts

Electric Charge, Current and Electromotive force, Potential and Potential Difference; Electrical Power and Energy; Ohm's Law, Resistance, Capacitance and Inductance, Series and Parallel Connection of Resistances and Capacitances, Kirchoff's Laws and Their Applications

AC Fundamentals:

Concept of Alternating Voltage and Current, RMS and Average Values, Single Phase and Three Phase Supply; 3-ph Star-Delta connections, Alternating Voltage applied to Pure Resistance, Inductance, Capacitance and their combinations, Concept of Power and Power Factor in AC Circuit.

Measuring Instruments:

Principle and Construction of Instruments used for Measuring Current, Voltage, Power and Energy, Methods and precautions in use of these.

Electromagnetic Induction:

Concept of Magnetic Field, Magnetic Flux, Reluctance, Magneto Motive Force (MMF), Permeability; Self and Mutual Induction, Basic Electromagnetic laws, various losses in magnetic circuits;

Electrical Machines:

Elementary concepts of an electrical machine, Basic principle of a motor and a generator, Classification of Electrical machines; Principles, Construction and Working of a machine; Starters: Need, Construction and Operation; Transformer: Classification, Principles, Construction and Working of a Transformer, Applications of Transformers;

Utilization of Electricity:

Utilization concepts of Electricity for electrolysis process, Electrochemical Cells & Batteries; Application of Electricity, Energy Conversation and Efficiency

Basic Troubleshooting:

Basic Testing and faults diagnosis in electrical systems, various tools and their applications, replacement of different passive components.

Electrical Safety:

Electrical Shock and Precautions against it, Treatment of Electric Shock; Concept of Fuses and Their Classification, Selection and Application; Concept of Earthing.

Text Books:

1. Edward Hughes, Electrical & Electronic Technology, Pearson, 12 th Edition, 2016.
2. Vincent Del Toro, Electrical Engineering Fundamentals, Pearson, 2 nd Edition, 2015.
3. V N Mittle and Arvind Mittal, Basic Electrical Engineering, Tata McGraw Hill, 2nd Edition, 2005.
4. E. Openshaw Taylor, Utilization of Electrical Energy, Orient Longman, 2010.
5. B.L.Theraja , Fundamentals of Electrical Engineering and Electronics volume -I, S Chand & Company 2005.
6. Ashfaq Husain, Fundamentals of Electrical Engineering, Dhanpat Rai & Sons 4 th edition, 2010.
7. H.Partab: Art & Science of Utilization of Electric Energy, Dhanpat Rai & Sons, 1998.
8. Fundamentals of Electrical Circuits by Charles k.Alexander, Mattew N.O.Saidiku, Tata McGraw Hill company.

BT101	BIOLOGY FOR ENGINEERS	ESC	2-0-0	2 Credits

Pre-requisites: None

Syllabus:
Importance of biology to engineers, Molecules of life: Water and Carbon, Evolution and origin of life, Darwins theory, Diversity of life, Chemical basis of life, Nucleic acids, Amino acids and Proteins, Carbohydrates, Lipids and Membranes.

Cell structure and function:
Prokaryotic, Eukaryotic cell and Virus, Sub cellular organelles and their functions, Regulation of cellular metabolism: Cellular respiration and Fermentation, Photosynthesis, Cell division (differences between mitosis and meiosis), Mendel's Law and Patterns of inheritance.

Gene structure and expression
Difference between prokaryotic and eukaryotic gene structure, DNA replication, Transcription, RNA processing and Translation, Control of gene expression (lac operon).

Applications of Biology in Engineering
Genetic engineering (microbe, plant and animal cells for improvement), Industrial Biotechnology (Primary and Secondary metabolites), Environmental engineering, Biopharmaceuticals, Tissue engineering, Biomaterials, Stem cell engineering, Biosensors, Bioinformatics.

Reference Books:

1. Quillin, Allison Scott Freeman, Kim Quillin and Lizabeth Allison, Biological Science, Pearson Education India, 2016.
2. Reinhard Renneberg, Viola Berkling and Vanya Loroch, Biotechnology for Beginners, Academic Press, 2017.

ME101	Basics of Mechanical Engineering	ESC	2-0-0	2 Credits

Syllabus:

Evolution of Mechanical Engineering: Introduction, Definition and scope of Mechanical Engineering, relation of Mechanical Engineering with other Engineering Disciplines, Revolutionary Inventions in wheels, tools, windmills, steam engine, CNC machines, Rapid Prototyping, Air-conditioning and Refrigeration, History of Mechanics, Thermodynamics and Heat Transfer, Production and Industrial Engineering, Mechatronics.

Engineering Materials: Introduction to Engineering Materials, Classification and Properties, Alloys. Composites, Micro and Nano Materials.

Manufacturing Processes: Castings - Patterns & Moulding, Metal forming, Hot Working and Cold Working Extrusion, Drawing, Rolling, Forging. Welding - Arc Welding & Gas Welding, Soldering, Brazing. Introduction to Machining processes – Lathe, Milling, Shaping, Drilling, Grinding, Introduction to NC/CNC Machines, 3D Printing.

Power Transmission: Transmission of Power, Belt Drives, Gears and Gear Trains -Simple Problems, **Fasteners and Bearings:** Fasteners - Types and Applications, Bearings - Types and Selection,

Thermodynamics: Introduction to Energy Sources - Thermodynamics - System, State, Properties, Thermodynamic Equilibrium, Process & Cycle, Zeroth law of Thermodynamics, Work & Heat, First law - Cyclic process, Change of State, Cp, Cv, Limitations of First law, Thermal Reservoirs, Heat Engine, Heat Pump/Refrigerator, Efficiency/COP, Second law, PMM2, Carnot Cycle, Entropy - T-S and P-V diagrams.

Introduction to Steam Turbines and I.C. Engines: I.C. Engines: 2-Stroke & 4-Stroke Engines, P-v Diagram; S.I. Engine, C.I. Engine, Differences.

Introduction to Heat Transfer and Refrigeration: Vapor Compression Refrigeration Cycle - Refrigerants, Desirable Properties of Refrigerants. Modes of Heat Transfer, Thermal Resistance Concept, Composite Walls & Cylinders, and Overall Heat Transfer Coefficient – problems.

Text Books:

1. Dixit, U.S., Hazarika, M. and Davim, J.P, A Brief History of Mechanical Engineering, Springer, 2017.
2. M.L. Mathur, F.S. Mehta and R.P. Tiwari, R.S. Vaishwnar, Elements of Mechanical Engineering, Jain Brothers, New Delhi, 2008.
3. Praveen Kumar, Basic Mechanical Engineering, Pearson Education, India, 2013.
4. P.N. Gupta, M.P. Poonia, Elements of Mechanical Engineering, Standard Publishers, 2004.
5. C.P. Gupta, Rajendra Prakash, Engineering Heat Transfer, NemChand Brothers, New Delhi, 1994.
6. B.S. Raghuvanshi, Workshop Technology, Vol. 1&2, Dhanpath Rai & Sons, New Delhi, 1989.

CE101	Engineering Mechanics	ESC	2-0-0	2 Credits

Prerequisites: None

Syllabus:

Introduction – Specification of force vector, Formation of Force Vectors, Moment of Force – Cross product – Problems, Resultant of a general force system in space,

Equillibrium of force system- Degrees of freedom – Equilibrium Equations, Degree of Constraints – Free body diagrams.

Coplanar Force Systems – Introduction – Equilibrium equations – All systems, Problems

Coplanar Concurrent force system, Coplanar Parallel force system, Coplanar General force system – Point of action, Method of joints, Method of sections, Method of members.

Friction in rigid bodies- Friction – Coulombs laws of dry friction – Limiting friction, Problems on Wedge friction, Belt Friction-problems.

Centroid & Moment of Inertia – Centroid and M.I – Arial – Radius of Gyration, Parallel axis– Perpendicular axis theorem – Simple Problems.

Dynamics of Particles – Introduction to kinematics- Equations of rectilinear motion, D'Alembert's principle -Simple problems- Introduction to kinetics- Work and Energy.

Text Books:

1. J.L.Meriam, L.G. Kraige, Engineering Mechanics, Statics, John Wiley &Sons,7th Edition, 2012.
2. A.K. Tayal, Engineering Mechanics, Umesh Publications, 14th Edition, 2010.
3. S S Bhavikatti and K G Rajashekarappa, Engineering Mechanics, New Age International Publication, 4th Edition.

Reference Books:

1. Dietmar Gross, Werner Hauger, Jorg Schroder, Wolfgang A. Wall, Nimal Rajapakse, Engineering Mechanics 1, Statics, Springer, 2nd Edition, 2013.
2. S. Timoshenko, D.H. Young, Pati Sukumar, J V Rao, Engineering Mechanics, Mc-Graw Hill, 5th Edition.

ME103	Workshop Practice	SD	0-1-2	2 Credits

Syllabus:

Fitting Shop: Preparation of T-Shape Work piece as per the given specifications, Preparation of U-Shape Work piece which contains: Filing, Sawing, Drilling, Grinding, and Practice marking operations.

Machine shop: Study of machine tools in particular Lathe machine (different parts, different operations, study of cutting tools), Demonstration of different operations on Lathe machine, Practice of Facing, Plane Turning, step turning, taper turning, knurling and parting and Study of Quick return mechanism of Shaping operation. Demonstration of the working of CNC and 3D Printing Machines.

Power Tools: Study of different hand operated power tools, uses and their demonstration and Practice of Power tools.

Carpentry: Study of Carpentry Tools, Equipment and different joints, Practice of Cross Half lap joint, half lap Dovetail joint and Mortise Tenon Joint.
Welding: Study of welding tools and welding equipment, Arc Welding Practice (Lap and Butt joint).

CY102	Engineering Chemistry Lab	BSC	0-0-2	2 Credits

List of experiments (any eight of the following):

Exp. No	Name of the experiment
1	Standardization of $KmnO_4$ solution
2	Determination of Iron in Haematite
3	Determination of Hardness of Water
4	Determination of available chlorine in bleaching powder and of iodine in Iodized salt
5	Ph-metric titration of an acid vs a base
6	Conductometric titration of an acid vs a base
7	Potentiometric titration of Fe^{2+} against $K_2Cr_2O_7$
8	Colorimetric determination of Potassium Permanganate
9	Determination of rate of Corrosion of mild steel in acidic environment in the absence of presence of an inhibitor
10	Determination of Chlorophyll in Olive oil by using UV and Fluorescence spectroscopic techniques
11	Functional group analysis of organic compounds by using IR spectroscopic technique
12	Organic solvent evaporation by using rotary-evaporation technique

Virtual labs

1. Determination of unknown concentration of analyte by using the Beer-Lambert's law.
2. Identification of unknown components using spectroscopic techniques.
3. Nuclear magnetic resonance spectroscopy and evolution of simple ^{1}H NMR spectra of organic compounds
4. Study of kinetics of a reaction by using spectrophotometric methods.

Reference books:

1. Charles Corwin, Introductory Chemistry laboratory manual: Concepts and Critical Thinking, Pearson Education, 2012.
2. David Collins, Investigating Chemistry: Laboratory Manual, Freeman & Co., 1st Edition, 2006.

II Year B.Tech Course Structure

MM201	Physical Metallurgy	PCC	3-0-0	3 credits

Pre-requisites: Engineering Physics, Engineering Chemistry

Course Outcomes: At the end of the course, student will be able to:

CO1	Explain the crystal structures and defects in crystals.
CO2	Describe the concepts of constitution of alloys.
CO3	Interpret important binary and ternary phase diagrams.
CO4	Apply theory of diffusion in materials.
CO5	Describe principles and applications of optical and electron microscopes.

Course Articulation Matrix:

CO \ PO/PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	S	L	-	-	-	-	-	-	-	-	-	-	-	L	-	L
CO2	S	-	-	-	-	-	-	-	-	-	-	-	-	M	-	
CO3	S	M	-	-	-	-	-	-	-	-	-	-	-	M	-	L
CO4	S	-	-	-	-	-	-	-	-	-	-	-	-	M	-	
CO5	M	-	-	M	M	-	-	-	-	-	-	-	-	M	-	S

S: Strong correlation, M: Medium correlation, L: Low correlation

Syllabus:

STRUCTURE OF METALS:

Crystal structure of metals – Space lattices, Bravais lattices, Coordination number, Relationship between lattice parameter and atomic radius, Packing factor and density calculation of structures, Miller – Bravais indices, Stacking sequence in cubic and HCP crystals, Tetrahedral and Octahedral voids.

CONSTITUTION OF ALLOYS:

Necessity of alloying, Substitutional, Interstitial and Ordered solid solutions, Hume Rothery Rules, Electro-chemical compounds, Electron phases and size factor compounds.

EQUILLIBRIUM DIAGRAMS:

Experimental methods for construction of equilibrium diagrams, Isomorphous systems, Phase rule and its applications, Lever rule, Equilibrium heating and cooling of an isomorphus alloy, Coring, Miscibility gaps, Eutectic systems, Congruent melting intermediate phases, Eutectoid, Peritectic, Peritectoid, Monotectic and Syntectic reactions. Study of important binary systems of Fe-Fe3C, Cu-Zn, Cu-Sn, Al-Cu and Al-Si. Ternary isomorphous and simple eutectic diagrams.

DIFFUSION IN SOLIDS:

Fick's law of diffusion, Solution to Fick's second law, Kirkendall effect, Darken's analysis, Atomic theory of diffusion, Diffusion Mechanisms.

MICROSCOPY:

Construction and Principles of Optical Microscope, Application and Limitation of Optical Microscope, Principle of Electron Microscope, Performance of Optical and Electron Microscopes.

Reference Books:

1. S. H. Avner, Introduction of Physical Metallurgy, Mc Graw Hill, 1987
2. V. Raghavan, Physical Metallurgy: Principles and Practice, PHI Learning, 2004
3. R E Reed Hill, Physical Metallurgy Principles, PWS Publishing, 2008
4. RE Smallman, Modern Physical Metallurgy, Butterworth-Heinemann, 2014

MM202	Principles of Extractive Metallurgy	PCC	3-0-0	3 Credits

Pre-requisites: None

Course Outcomes: At the end of the course, student will be able to:

CO1	Discuss basic unit operations of minerals/ores used for metals extraction
CO2	Apply Ellingham diagrams and basic thermodynamic principles for extraction of metals
CO3	Summarize unit processes and principles employed in pyro-, hydro- and electro-metallurgy for mineral beneficiation, refinement and metal extraction.
CO4	Explain reaction kinetics, heat & material balance and process flow sheets for the extraction of non-ferrous metals

Course Articulation Matrix:

CO \ PO/PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	S	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-
CO2	S	M	-	-	-	-	-	-	-	-	-	-	L	-	-	-
CO3	M	-	-	-	-	-	-	-	-	-	-	-	M	-	-	-
CO4	M	-	M	-	-	-	-	-	-	-	-	-	M	-	-	-

S: Strong correlation, M: Medium correlation, L: Low correlation

Syllabus:

INTRODUCTION:

Scope of extractive metallurgy, occurrence of metals in nature, minerals and ores. Elementary concepts of Mineral processing, Theories of Comminution. Crushing and grinding equipment, their fields of application and limitations, Laws of settling of solids in fluid, Types of classifiers, their selection and performance.

PYROMETALLURGY:

Drying and calcination, roasting & derivation of roasting conditions by Kellogs's diagram, relevance of Ellingham diagram in metal extraction, reduction of metal oxides, matte smelting and converting, metal refining processes: fire-refining, liquation and distillation.

HYDROMETALLURGY:

Leaching and its methods, construction & use of Pourbax diagram, bioleaching, solution purification and concentration: solvent extraction and ion exchange. Recovery of metals from leach solutions.

ELECTROMETALLURGY:

Principles of electrolysis, electrolytic systems, electro-refining, electro-winning and other electro-metallurgical processes.

PROCESS FLOW SHEETS:

Production of iron and steel, aluminum, copper, zinc and lead. Analysis of unit processes: Reactor kinetics, heat and material balance.

Reference Books:

1. H.S. Ray and A. Ghosh, Principles of Extractive Metallurgy, New Age International, 1991
2. S.K. Dutta, A.B. Lele, Y.B. Chokshi, Extractive Metallurgy: Processes and Applications, PHI Learning, 2018
3. Alain Vignes, Extractive Metallurgy 1: Basic thermodynamics and kinetics, Wiley-ISTE, 2013
4. Alain Vignes, Extractive Metallurgy 2: Metallurgical Reaction Processes, Wiley-ISTE, 2013
5. Alain Vignes, Extractive Metallurgy 3: Processing operations and Routes, Wiley-ISTE, 2013

MM203	Metallurgical Thermodynamics and Kinetics	PCC	3-0-0	3 Credits

Pre-requisites: Mathematics-II

Course Outcomes: At the end of the course, student will be able to:

CO1	Apply the laws of thermodynamics with reference to metallurgical processes and materials
CO2	Calculate the heat and energy requirements and efficiencies of metallurgical processes
CO3	Identify the feasibility of metallurgical processes and reactions.
CO4	Summarize the kinetics of metallurgical processes and design the alloy systems by applying the concepts of thermodynamics

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Course Articulation Matrix:

PO/PSO CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	S	L	-	-	-	-	-	-	-	-	-	-	L	L	-	-
CO2	M	S		-	-	-	-	-	-	-	-	-	M	M	-	-
CO3	-	-	M	-	-	-	-	-	-	-	-	-	L	L	-	-
CO4	-	L	S	-	-	-	-	-	-	-	-	-	-	M	-	-

S: Strong correlation, M: Medium correlation, L: Low correlation

Syllabus:

FUNDAMENTALS:

Basic concepts and definitions-Thermodynamic systems, thermodynamic variables, thermodynamic processes, cycle and equilibrium, reversible and irreversible processes, zeroth law of thermodynamics.

FIRST LAW OF THERMODYNAMICS:

Internal energy, Enthalpy, Constant volume and constant pressure process; Isothermal and adiabatic process. Heat capacity, Enthalpy of physical transformations and chemical reactions, Hess's law and Kirchhoff's law and applications, Thermochemistry.

SECOND LAW OF THERMODYNAMICS:

Entropy and disorder, Configurational entropy and thermal entropy; calculation of entropy change from heat capacities, variation of entropy with temperature, Principle of increase in entropy, Combined statement of I and II laws, Thermodynamic equation of state, Applications of thermodynamic equations of state. Free energy functions, Properties of the Gibbs energy, Calculation of Gibbs free energy, Variation of Gibbs energy with temperature and pressure. Maxwell's relations, Gibbs- Helmholtz equation.

THIRD LAW OF THERMODYNAMICS:

Clausius-Clapeyron equation and its uses. Fugacity, Activity and Equilibrium constant, variation of equilibrium constant with temperature. Concept of chemical potential, Gibbs phase rule and its derivative, Applications of Gibbs phase rule.

SOLUTION THERMODYNAMICS:

Composition, Concept of partial molal quantities, Gibbs-Duhem equation, determination of partial molal quantities, Interrelation of partial molal quantities for solutions of fixed composition, thermodynamic properties of binary solutions; ideal, non-ideal and regular solutions, Raoult's law, Henry's law and Sievert's law, Concept of activity coefficient, Integration of Gibbs-Duhem equation, Excess thermodynamic quantities.

METALLURGICAL KINETICS:

Heterogeneous reaction; Gas-solid, solid-liquid, liquid-liquid and solid-solid systems. Empirical and Semiempirical Kinetics, Concept of Johnson-Mehl equation, Thermal analysis.

Text Books:

1. D. R. Gaskell, Introduction to Thermodynamics of Materials, Taylor & Francis, 2018
2. R. T. DeHoff, Thermodynamics in Materials Science, McGraw Hill, 1993
3. G.S.Upadhyaya & R.S.Dube, Problems in Metallurgical Thermodynamics and Kinetics, Pergamon, 1977
4. A. Ghosh, Text Book of Materials and Metallurgical Thermodynamics, Prentice Hall India, 2003
5. R.W. Balluffi, S.M. Allen, and W.C. Carter, Kinetics of Materials, Wiley, 2005
6. H. S. Ray & S.Ray, Kinetics of Metallurgical Processes, Springer, 2018

MM204	Transport Phenomena	PCC	3-0-0	3 Credits

Prerequisite: Mathematics-II

Course Outcomes: At the end of the course, student will be able to:

CO1	Apply basics of mass and momentum transfer in the extraction and refining of metals
CO2	Apply concepts of heat transfer in designing furnaces and thermomechanical treatment of materials
CO3	Calculate material and energy balances in material flow systems
CO4	Illustrate simultaneous momentum, heat and mass transfer in metallurgical reaction systems

Course Articulation Matrix:

PO PSO / CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2	PSO 3	PSO 4
CO1	S	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-
CO2	L	-	S	-	-	-	-	-	-	-	-	-	-	S	-	-
CO3	-	S	-	-	-	-	-	-	-	-	-	-	S	-	-	-
CO4	-	M	S	-	-	-	-	-	-	-	-	-	M	M	-	-

S: Strong correlation, M: Medium correlation, L: Low correlation

Syllabus:

INTRODUCTION:

Unit operations in chemical metallurgy, engineering fundamentals of unit processes

MOMENTUM TRANSFER:

Fluid Flow, Properties of fluids, Newton's law of viscosity, Molecular theory of viscosity of gas/liquid, Types of fluid flow, Reynolds experiments, Equation of continuity and motion, Momentum transfer in fluid, Shell momentum balance and velocity profile, concept of velocity boundary layer, Navier stroke equation and its applications, flow past submerged bodies, fluid flow in packed bed, Law of conservation of energy, Bernoulli's equation, Friction in pipes and channels, fans, pumps, blowers, compressors, fan laws

HEAT TRANSFER:

Fourier's law of heat conduction in solids, conduction in liquids and gases, steady state and unsteady state conduction in solids, Natural convection, Forced convection, concept of heat transfer coefficient and thermal boundary layer, Radiation heat transfer, Gurney-Lurie, Haisler, Hottel and allied charts. Heat transfer with change of phase. Introduction to solidification heat transfer and ablation, Heat transfer in packed and fluid beds.

MASS TRANSFER:

Diffusivity and steady state diffusion, Darken's equation, Kirkendall's effect, Unsteady state mass transfer, concept of mass transfer coefficient concentration boundary layer, Inter-phase mass transfer – theories, introduction to simultaneous mass and heat transfer. Classification of diffusional operations and conduction of diffusional operations, introduction to stage operations. Similarity criteria and introduction to model and pilot plant studies, Similarities of momentum, mass and energy transfer.

Text Books:

1. G. H. Geiger, D. R. Poirier, Transport phenomena in Materials Processing, John Wiley& Sons, 2010
2. A. K. Mohanty, Rate Processes in Metallurgy, PHI, 2012
3. David R Gaskell, An Introduction to Transport Phenomena in Materials Engineering, Momentum Press, 2013
4. N J Themelis, Transport and Chemical Rate Phenomena, Routledge, 2004
5. R. B. Bird, W.E. Stewart, E.N. Lightfoot, Transport phenomena, Wiley- India, 2011
6. Julian Szekely, Fluid Flow Phenomena in Metals Processing, Academic Press, 1980
7. G. S. Upadhyaya and R. K Dube, Problems in Metallurgical Thermodynamics and Kinetics, Pergamon, NewYork, 1982

MM205	Physical Metallurgy and Metallography Laboratory	PCC	0-0-3	2 Credits

Pre-requisites: None

Course Outcomes: At the end of the course, student will be able to:

CO1	Describe the techniques of specimen preparation for metallography
CO2	Prepare ferrous and non-ferrous samples for metallography.
CO3	Use metallurgical microscope to observe microstructures of ferrous and non-ferrous metals
CO4	Determine the grain size, shape and volume fraction of phases.

Course Articulation Matrix:

PO/PSO CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	L	-	-	-	-	-	-	-	L	-	-	L	-	L	-	-
CO2	-	M		M	-	-	-	-	-	-	-	-	-	-	-	S
CO3	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	S
CO4	-	S	-	-	-	-	-	-	-	M	-	-	-	-	-	S

S: Strong correlation, M: Medium correlation, L: Low correlation

List of experiments:

1. To prepare an alloy (Steel / Al / Cu) sample for Microstructural Analysis: Sample preparation for metallography: sandpaper polishing, cloth polishing, electropolishing
2. To etch the polished sample. Etching of polished samples - ferrous and nonferrous specimens
3. To examine the Microstructure of etched sample and identify the phases.
4. Quantitative metallography and image analysis
5. To measure the Grain size using line intercept method and ImageJ software.
6. To Calculate volume fraction of phases

Reference Books:

1. Physical Metallurgy and Metallography Laboratory manual

MM206	Extractive Metallurgy Laboratory	PCC	0-0-3	2 Credits

Pre-requisites: None

Course Outcomes: At the end of the course, student will be able to:

CO1	Carryout electrodeposition of metals
CO2	Carryout electroplating of metals
CO3	Measure electrochemical parameters
CO4	Extraction of metals from oxide ores

Course Articulation Matrix:

CO \ PO/PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	-	-	-	-	S	-	-	-	-	-	-	-	S	-	-	-
CO2	-	-	-	-	S	-	-	-	-	-	-	-	S	-	-	-
CO3	-	-	-	-	S	-	-	-	-	-	-	-	S	-	-	-
CO4	-	-	M	-	-	-	-	-	M	M	-	-	S	L	-	-

S: Strong correlation, M: Medium correlation, L: Low correlation

List of experiments:

1. Calcination of the given sample of limestone and report the degree of calcinations
2. Reduction of cupric oxide carbo-thermically and calculate percentage of reduction
3. Study the effect of time on the amount of copper deposited on steel plates during cementation
4. Leaching of metal oxide ores to extract corresponding metal
5. Anodize the given aluminum sample and color the sample with a dye and seal the pores
6. Electroplating of copper coating on a given electrode through reduction of Cu ions
7. Electroplating of nickel coating on a given electrode through reduction Ni ions
8. Study the throwing power of a given electrolytic bath to deposit metal of uniform thickness

Reference Books:

1. Extractive Metallurgy Laboratory manual

MM251	Phase Transformations and Heat Treatment	PCC	3-0-0	3 Credits

Pre-requisites: MM201-Physical Metallurgy

Course Outcomes: At the end of the course, student will be able to:

CO1	Explain the concepts of phase transformations in metals and alloys.
CO2	Apply TTT and CCT diagrams to interpret microstructural development in steels.
CO3	Discuss industrial heat treatment techniques to engineer microstructure for optimization of mechanical properties in metals and alloys.
CO4	Apply surface modification concepts for betterment of industrial components.

Mapping of course outcomes with program outcomes

PO /PSO CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2	PSO 3	PSO 4
CO1	S	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-
CO2	-	-	S	-	-	-	-	-	-	-	-	-	-	S	L	-
CO3	1	-	S	-	-	-	-	-	-	-	-	-	-	-	M	-
CO4	-	-	S	-	-	-	-	-	-	-	-	-	-	L	S	-

S: Strong correlation, M: Medium correlation, L: Low correlation

Syllabus:

PHASE TRANSFORMATIONS:

Phase Transformations of Materials, Application of Nucleation and Growth concept in Phase Transformations, Study of Fe-Fe3C phase diagram, Phase transformations in Steels, Austenite GrainGrowth, Determination of Austenite Grain Size, Isothermal Transformation Diagrams, Pearlite, Bainite and Martensite Transformations, CCT, Effect of Alloying on TTT / CCT Curves.

PRINCIPLES OF HEAT TREATMENT:

Annealing, Normalising, Hardening and Tempering of Steels, Hardening Defects, Temper Embrittlement, Subzero treatment, Mechanism of heat removal during Quenching, Quenching Media, Residual Stress and Quench Cracks. Martempering and Austempering. Hardenability and its Measurement, Effect of alloying on Hardenability.

HEAT TREATMENT OF ALLOY STEELS:

Classification of Alloy Steels, Advantages and Disadvantages of Alloy Steels, Heat Treatment of HSLA, Tool Steels, Hadfield Mn Steel, Stainless Steels.

HEAT TREATMENT OF CAST IRONS:

Structure-Property Correlation of different Cast Irons, Manufacturing of Cast Irons, Heat Treatment of Cast Irons – Malleabilisation, Austemper Ductile Irons, Application of Alloy Cast Irons.

AGE HARDENING:

Concept of Age Hardening, Steps of Age Hardening, Application of Age Hardening, Study of Age Hardened Alloys (ferrous/ nonferrous).

CASE HARDENING AND SURFACE TREATMENTS:

Carburising, Nitriding, Cyaniding, Carbonitriding, Nitrocarburising and Boronising. Case Depth Measurement - Flame, Induction and Laser Hardening of Alloys, Industrial Heat Treatment Practices, Case Studies.

Text Books:

1. D. A. Porter, K. E. Easterling, M.Y. Sherif, Phase Transformation in Metals and Alloys, CRC press, 2009
2. R. C. Sharma, Phase Transformations in Materials, CBS Publishers, 2017
3. V. Raghavan, Solid State Transformations, Prentice-Hall India, 1987
4. T.V. Rajan & C.P. Sharma, Heat Treatment: Principles and Techniques, PHI, 1994

MM252	Non-Ferrous Extractive Metallurgy	PCC	3-0-0	3 Credits

Pre-requisites: MM202-Unit Processes in Extractive Metallurgy, MM203-Metallurgical Thermodynamics

Course Outcomes: At the end of the course, student will be able to:

CO1	Identify techniques for extraction and refining of non-ferrous metals.
CO2	Differentiate extraction of various non-ferrous metals..
CO3	Design flow sheets for extraction and refining of metals.
CO4	Assess energy efficiency in extraction of Aluminum.

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Course Articulation Matrix

PO/PSO CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	S	-	-	-	-	-	-	-	-	-	-	-	M	M	-	-
CO2	S	-	-	-	-	-	-	-	-	-	-	-	M	M	-	-
CO3	S	-	-	-	-	-	-	-	-	-	-	-	M	M	-	-
CO4	S	-	-	-	-	-	-	-	-	-	-	-	M	M	-	-

S: Strong correlation, M: Medium correlation, L: Low correlation

Syllabus:

INTRODUCTION

Early developments in metal extraction, Sources of non-ferrous metals

EXTRACTION OF METALS FROM OXIDE SOURCES

Basic approaches and special features of specific extraction processes, extraction of metals such as magnesium, aluminum, tin.

EXTRACTION OF METALS FROM SULPHIDE ORES

Pyro-metallurgy and hydro-metallurgy of sulphides, production of metals such as copper, lead, zinc, nickel etc.

EXTRACTION OF METALS FROM HALIDES

Production of halides and refining methods, production of reactive and reactor metals. Methods of extraction of metals such as titanium, rare earths, uranium, thorium, plutonium, beryllium, zirconium etc.

EXTRACTION OF PRECIOUS METALS

Extraction of gold, silver and pt. group of metals

Text Books:

1. H. S. Ray, R. Sridhar and K.P. Abraham, Extraction of Non-Ferrous Metals, Affiliated East-West press, 2008
1. R. Raghavan, Extractive Metallurgy of Non-Ferrous Metals, Vijay Nicole Imprints, 2016
2. Roger Rumbu, Non-Ferrous Extractive Metallurgy - Industrial Practices, Createspace Independent pub, 2015
3. Alain Vignes, Extractive Metallurgy 1: Basic thermodynamics and kinetics, Wiley-ISTE, 2013
4. Alain Vignes, Extractive Metallurgy 2: Metallurgical Reaction Processes, Wiley-ISTE, 2013
5. Alain Vignes, Extractive Metallurgy 3: Processing operations and Routes, Wiley-ISTE, 2013

MM253	Casting and Solidification	PCC	3-0-0	3 Credits

Pre-requisites: MM201-Physical Metallurgy, MM203-Metallurgical Thermodynamics

Course Outcomes: At the end of the course, student will be able to:

CO1	Explain the principles of solidification in metals and alloys
CO2	Correlate the morphogenesis of solidification microstructures with the heat and mass transfer conditions
CO3	Describe the casting techniques
CO4	Design the gating and risering of castings
CO5	Identify the melting furnaces for metals and alloys

Course Articulation Matrix:

CO \ PO/PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	-	-	M	-	-	-	-	-	-	-	-	-	-	M	-	-
CO2	S	M	M	-	-	-	-	-	-	-	-	-	-	M	-	-
CO3	-	-	S		L	-	-	-	-	-	-	-	-	-	M	-
CO4	-	S	S	M`	-	-	-	-	-	-	-	-	S	-	-	L
CO5	-	M	-	-	-	-	-	-	-	-	-	-	-	-	M	-

S: Strong correlation, M: Medium correlation, L: Low correlation

Syllabus:

CASTING:

Steps in casting process, pattern making, mold and core making, riser and gate design, melting equipment for casting, fluidity considerations, solidification time, Chvorinov's rule, Pattern allowances - shrinkage allowance, draft allowance, machining allowance, shake/rapping allowance, distortion/camber allowance.

TYPES OF CASTING PROCESSES

Sand casting, Investment casting, Die casting, Low pressure casting, Centrifugal casting, Gravity die casting, Vacuum die casting, Squeezing die casting; Ingot casting and continuous casting of steels

DEFECTS IN CASTING

defects in castings and quality control, fettling and repair of castings, heat treatment of castings.

SOLIDIFICATION:

Pure metal solidification, alloy solidification, thermal undercooling, homogeneous and heterogeneous nucleation, growth kinetics, solute diffusion, constitutional undercooling, nature of the solid-liquid interface, planar, cellular and dendritic interfaces and growth, continuous growth, lateral growth, microsegregation, macrosegregation, shrinkage, zones in cast structure, Poly/multiphase solidification: eutectic, peritectic, and monotectic reactions, directional solidification, single crystal growth, rapid solidification processing.

Text Books:

1. M.C.Fleming, Solidification Processing, McGraw Hill, 1974
2. W. Kurz & D.J. Fisher, Fundamentals of solidification, Trans Tech publications, 1998
3. Doru Stefanescu, Science and Engineering of Casting Solidification, Springer, 2009
4. M.E. Glicksman, Principles of Solidification, Springer, 2011
5. Peter Beeley, Foundry Technology, Butterworth-Heinemann, 2001
6. P. L. Jain: Principles of foundry technology, Tata McGraw Hill, 2009
7. R. Heine, C. Loper, P. Rosenthal, Principles of Metal Casting McGraw Hill, 2017

MM254	Phase Transformations and Heat Treatment Laboratory	PCC	0-0-3	2 Credits

Pre-requisites: MM201-Physical Metallurgy

Course Outcomes: At the end of the course, student will be able to:

CO1	Practice industrial heat treatment processes for ferrous and nonferrous alloys.
CO2	Observe microstructure using optical and scanning electron microscopes.
CO3	Evaluate the hardenability of steels by Jominy end quench test.
CO4	Conduct microstructure-property correlation of heat treated samples.

Course Articulation Matrix:

CO \ PO/PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	-	-	-	M	S	-	-	-	S		-	-	-	S	-	L
CO2	-	-	-	-	S	-	-	-			-	-	-	-	-	S
CO3	-	-	-	S	M	-	-	-		M	-	-	-	-	-	M
CO4	-	S	-	`-	-	-	-	-	M	M	-	-	-	-	-	S

S: Strong correlation, M: Medium correlation, L: Low correlation

List of Experiments:

1. To study Microstructure of Annealed steel samples
2. To study Microstructure of Normalized steel samples
3. To study the Microstructure of Hardened Steels (oil quenching, agitated oil quenching, water quenching, agitated water, flowing water quenching,
4. To study Microstructure of tempered steel samples
5. Jominy End Quench Test and Hardness testing
6. Ageing treatment of Aluminum alloy

Text Books:

1. Phase Transformations & Heat Treatment Laboratory

MM255	Casting and Solidification Laboratory	PCC	0-0-3	2 Credits

Pre-requisites: None

Course Outcomes: At the end of the course, student will be able to:

CO1	Determine moulding sand properties.
CO2	Demonstrate the preparation of moulds
CO3	Demonstrate melting practice
CO4	Demonstrate casting of metals/alloys.
CO5	Identify various kinds of casting defects

Course Articulation Matrix:

PO /PSO CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2	PSO 3	PSO 4
CO1	-	-	-	S	L	-	-	-	-	-	-	-	-	-	L	S
CO2	-	-	-	-	S	-	-	-	S	-	L	-	-	-	S	-
CO3	-	-	-	-	S	-	-	-	S	-	-	-	-	-	S	-
CO4	-	-	-	-	S	-	-	-	S	-	-	-	-	-	S	-
CO5	-	S	-	-	S	-	-	-		S	-	-	-	-	M	-

S: Strong correlation, M: Medium correlation, L: Low correlation

List of experiments:

1. Sand Testing: Green and dry strength testing, Determination of permeability, Shatter index, clay content, Moisture content
2. Mould preparation and Pattern making
3. Demonstration of Melting and casting in sand molds, metal molds
4. Casting of metals using induction furnace
5. Casting defect investigation

Reference Books:

Casting and Solidification Laboratory manual

ME235	Strength of Materials	PCC	4-0-0	4 Credits

Pre-Requisites: CE 101: Engineering Mechanics
Course Outcomes: At the end of the course, the student will be able to:

CO1	Understand the basic Mechanical properties of materials and testing procedure of materials
CO2	Understand statically determinate and indeterminate problems. Analyze thin cylinders and deflection of beam
CO3	Determine the resistance and deformation in machine members subjected to axial, flexural and torsional loads.
CO4	Evaluate principal stresses, strains and apply the concept of failure theories for design.

Syllabus:
Mechanical Fundamentals of materials and Testing: Basic assumptions of materials, Testing of materials-Non-Destructive Testing, Tensile testing, compression testing - Hardness Testing-Impact testing, Fatigue testing, Creep, other related testing methods characterization of TEM, XRD, SEM,
Resistance and Deformation: Concept of Resistance and deformation - Determinate and Indeterminate problems in Tension and Compression - Thermal Stresses - pure shear - young's modulus of elasticity, Poisson's ratio, Modulus of rigidity and Bulk modulus - Relation between elastic constants - Stress-strain diagrams for brittle and ductile materials - working stress - Strain energy in tension and compression - Impact loading.
Thin Cylinders: Thin Cylinders - spherical shells subjected to internal fluid pressure - Wire wound thin cylinders - Compound cylinders - Shrink fit.
Shear Force and Bending Moment: Types of supports - Types of beams - Types of loads - articulated beams - Shear Force and Bending Moment diagrams.
Theory of Simple Bending: Assumptions - Bending stresses in beams - Efficiency of various cross sections - Composite beams.
Shear Stress Distribution: Flexural shear stress distribution in different cross sections of beams.
Torsion of Circular cross sections: Theory of pure torsion - transmission of Power in Solid and Hollow circular shafts - Combined bending and torsion.
Principal Stresses and Strains: Analysis of Biaxial state of stress with and without shear - Mohr's Circle
Theories of failure: Dilation - Distortion - Maximum Principal Stress Theory - Maximum Principal Strain Theory - Maximum Shear Stress Theory - Strain Energy Theory - Distortion energy theory.

Text Books:

1. Goodno, Barry J., and James Gere. Statics and Mechanics of Materials. Cengage Learning, 2018.
2. Shames, I. H., & Pitarresi, J. M. Introduction to Solid Mechanics, 2000.
3. Timoshenko and Gere, Mechanics of Materials, CBS Publishers, 2011.
4. E.P.Popov, Engineering Mechanics of Solids, PHI, 2009.
5. S. B. Junarkar, Mechanics of Structures, Charotar Publishers, 2010.
6. George E. Dieter, Mechanical Metallurgy, Mc Graw Hill,3rd Edition,2017
7. Suryanarayana AVK, Testing of Metallic Materials,BS Publications,2nd Edition, 2007.

MA253	**Transform Techniques and Numerical Methods**	**BSC**	**3 - 0 - 0**	**3 Credits**

Pre-requisites: Differential & Integral Calculus (MA101),
Matrices & Differential Equations (MA151).

Course Outcomes: At the end of the course, student will be able to:

CO1	Obtain the Fourier series for a given function
CO2	Find the Fourier transform of a function and Z- transform of a sequence
CO3	Determine the solution of a PDE by variable separable method
CO4	Interpret an experimental data using interpolation / curve fitting
CO5	Solve numerically algebraic/transcendental and ordinary differential equations

Course Articulation Matrix:

PO / CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1												
CO2												
CO3												
CO4				`								
CO5												

Syllabus:

Fourier Series: Expansion of a function in Fourier series for a given range - Half range sine and cosine expansions

Fourier Transforms: Fourier transformation and inverse transforms - sine, cosine transformations and inverse transforms - simple illustrations

Z-Transforms: Z- transform and Inverse Z-transforms – Properties – convolution theorem- simple illustrations.(6)

Partial Differential Equations: Method of separation of variables - Solution of one dimensional wave equation, one dimensional heat conduction equation and two dimensional steady state heat conduction equation with illustrations.

Numerical Methods: Curve fitting by the method of least squares. Fitting of (i) Straight line (ii) Second degree parabola (iii) Exponential curves - Gauss-Seidal iteration method to solve a system of equations -Numerical solution of algebraic and transcendental equations by Regula-Falsi method and Newton-Raphson's method - Lagrange interpolation, Forward and backward differences, Newton's forward and backward interpolation formulae - Numerical differentiation with forward and backward differences - Numerical Integration with Trapezoidal rule, Simpson's 1/3 rule and Simpson's 3/8 rule - Taylor series method, Euler's method, modified Euler's method, 4th order Runge-Kutta method for solving first order ordinary differential equations.

Text Books:

1. R. K. Jain and S. R. K. Iyengar, *Advanced Engineering Mathematics,* Narosa Pub. House,Fifth edtion, 2016.
2. E. Kreyszig, *Advanced Engineering Mathematics*, John Wiley and Sons, 8th Edition, 2008.
3. B. S. Grewal, *Higher Engineering Mathematics*, Khanna Publications, 44th edition, 2017.
4. M. K. Jain, S. R. K. Iyengar and R. K. Jain, Numerical methods for Scientific and Engineering Computation, New Age International Publications, 2008.

EE257	Numerical analysis using Python	ESC	2 - 1 - 2	4 Credits

Pre-requisites: Basic mathematics, Basic programming
Course Outcomes: At the end of the course, student will be able to:

CO1	Understand a variety of numerical analysis tools that are useful for solving science and engineering problems
CO2	Understand the programming language Python
CO3	Solve linear and nonlinear equations using numerical methods
CO4	Solve ordinary differential equations and partial differential equations using numerical methods

Syllabus:
Basic elements of programming: Data Structures, Loops, Conditionals, Functions, Plotting.
Python programming basics, Variables and Basic Data Structures, Functions, Branching Statements, Iteration, Recursion, Object Oriented Programming (OOP), Complexity, Representation of Numbers, Errors, Good Programming Practices, and Debugging, Reading and Writing Data, Visualization and Plotting.
Numerical methods: Integration, Differentiation, Differential Equations, Basic Regression
Linear Algebra and Systems of Linear Equations, Eigenvalues and Eigenvectors, Least Squares Regression, Interpolation, Series, Root Finding, Numerical Differentiation, Numerical Integration, Ordinary Differential Equation - Initial Value Problems, Ordinary Differential Equation - Boundary Value Problems, Fourier Transform

Text Books:

1. Q. Kong, T. Siauw, A. Bayen, Python Programming And Numerical Methods: A Guide For Engineers And Scientists, Academic Press 2020.
2. J. Kiusalaas, Numerical Methods in Engineering with Python, Cambridge University Press 2013.
3. C. F. Gerald and P.O. Wheatley, Applied Numerical Analysis, Pearson Education India, 2004

III Year B.Tech Course Structure

MM301	Iron Making and Steel Making	PCC	3-0-0	3 Credits

Pre-requisites: MM203-Metallurgical Thermodynamics and Kinetics

Course Outcomes: At the end of the course, student will be able to:

CO1	Explain raw materials and basic principles of iron and steel making
CO2	Discuss different manufacturing methods for iron and steel making
CO3	Describe the physico-chemical phenomena occurring in iron and steel making processes
CO4	Suggest alternate routes of iron and steel making.

Course Articulation Matrix:

CO \ PO/PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	S	M	-	L		-	-	-	-	-	-	-	S	-	-	-
CO2	S	-	-		M	-	-	-	-	-	-	-	S	M	-	-
CO3	S	M	-	-	-	-	-	-	-	-	-	-	S	L	-	-
CO4	S	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-

S: Strong correlation, M: Medium correlation, L: Low correlation

Syllabus:

HISTORY OF IRON AND STEEL MAKING:

Importance of Iron and Steel for the modern society, Indigenous iron and steel making processes, Developments that led to modern iron and steel making

IRON MAKING:

Preparation of burden materials such as coal, coke, limestone, dolomite; Sintering and pelletization of iron ore; Testing of burden materials, Blast furnace and its accessories, Operational procedures in blast furnace, Thermal, Physical, and Chemical process in a blast furnace, Blast furnace slag and its control, Control of hot metal composition, Removal of impurities such as Phosphorous, Sulfur, and Silicon from blast furnace hot metal iron, Control of irregularities in the blast furnace, Performance of blast furnace over the years, Modern trends in blast furnace design and practice

ALTERNATE ROUTES OF IRON MAKING:

Alternate routes of iron production, Sponge iron production, direct reduction and Smelting-reduction processes.

STEEL MAKING:

Earlier methods of steelmaking - Bessemer process and open-hearth process; Modern methods of steelmaking - Basic oxygen furnace process and Electric arc furnace process; Thermodynamic and kinetic aspects in steelmaking, Physical chemistry of slag-metal and gas-metal reactions. Alternative Steel making processes.

SECONDARY STEELMAKING AND STEEL CASTING

Ladle metallurgy, impurity removal, degassing, inclusion engineering and production of clean steels. Continuous casting process flow description, casting products, casting defects; Near-net manufacturing of steel.

VARIOUS STEEL CATEGORIES:

Carbon Steels: Low Carbon, Medium Carbon and High Carbon Steels

Stainless Steels: Ferritic, Austenitic, Martensitic, Duplex and Precipitation Hardened Steels

Alloy Steels: Aluminum, Copper, Manganese, Molybdenum, Tungsten, Silicon.

Tool Steels: Air-Hardened, Water-Hardened, Oil-Quenched, High Speed, Hot-worked and Shock Resistant.

Text Books:

1. Ahindra Ghosh and Amit Chatterjjee, Ironmaking and steelmaking: Theory and practice, PHI learning private limited, 2008.
2. S.K. Dutta, Y. B. Chokshi, Basic Concepts of Iron and Steel Making, Springer, 2020
3. R. J. Fruehan (ed.), The making, shaping and treating of steel, AISE, 1998.
4. Seshadri Seetharaman (ed.), Treatise on Process Metallurgy, Volume 3, Industrial Processes, Part A, Elsevier, 2014.
5. Dipak Mazumdar, James W. Evans, Modeling of steelmaking processes, CRC press, 2010.
6. R. H. Tupkary and V. R. Tupkary, Production of Steel: Theory and Practice, Tupkary Publication, 2021
7. R. H. Tupkary and V. R. Tupkary, An Introduction to Modren Steel Making, Khanna Publication, 2000

MM302	Mechanical Behaviour of Materials	PCC	3-0-0	3 Credits

Pre-requisites: MM201-Physical Metallurgy

Course Outcomes: At the end of the course, student will be able to:

CO1	Explain the theories of elastic and plastic behaviour of materials.
CO2	Differentiate mechanical testing methods of materials.
CO3	Discuss the strengthening mechanisms of materials
CO4	Appreciate the failure mechanisms in materials

Course Articulation Matrix:

PO/PSO / CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	S	-	-	-		-	-	-	-	-	-	-	-	M	-	-
CO2	S	-	-	-	M	-	-	-	-	-	-	-	-	-	-	S
CO3	S	-	L	-	-	-	-	-	-	-	-	-	-	M	-	-
CO4	S	-	-	M	-	-	-	-	-	-	-	-	-	-	-	M

S: Strong correlation, M: Medium correlation, L: Low correlation

Syllabus:

INTRODUCTION:
Elastic and plastic behaviour of materials, Concept of stress and strain, Important Mechanical Properties.

DISLOCATION THEORY:

Imperfections in Solids, Concept of dislocations, Edge, Screw and mixed dislocation, Burger Vector, Stress field around dislocation; Dislocation Movement, Dislocation Glide and climb, Force acting on dislocations, Core of the dislocation and the Peierls Stress, Nabarro stress, Energy of dislocations, Forces between Dislocations, dislocation and plastic strain, Dissociation or Combination of Dislocations, Dissociation Criterion, Glide plane of dislocation, Dislocation-Precipitate Interactions, Frank-Read Source: Dislocation Multiplication, Deformation by Twinning, Jogs and Kinks, Dislocation Pileups, Geometrically necessary dislocation.

STRENGTHENING MECHANISMS:

Introduction, types of strengthening mechanisms, Solid Solution Strengthening, Strain Hardening, Grain boundary strengthening, strengthening from second phase: Factors influencing second-phase particle strengthening, Precipitation Hardening, Precipitation Sequence-GP Zones, Factors affecting precipitation hardening, Interaction between particles and dislocations-Particle Cutting and Orowan mechanism, Coherent and Incoherent Precipitates, Dispersion Strengthening, Fibre Strengthening.

MATERIAL PROPERTY TESTING METHODS:

Hardness test: Definition and types, Mohs' scale; Brinell hardness; Meyer hardness, Meyer's law; Rockwell hardness; Vickers hardness; Microhardness-Vickers and Knoop; Rebound/Dynamic hardness-Shore hardness, Leeb Tester, Instrumental Hardness.

Tension test: Elastic and plastic deformation, Time Independent and time dependent Deformation, Tension Test Setup and specimens, Typical Stress strain diagram and properties derived from it, Elastic strain recovery, Instability in tension, necking criterion, Yield Point Phenomenon, Strain Aging, Dynamic strain ageing.

Compression test: Needs of compression test, Compression Test Setup and specimens, Behaviour of ductile and brittle materials in Compression, Barreling

Impact testing: The brittle failure problem and notch sensitivity, notched bar impact test; Ductile to Brittle transition temperature (DBDT); Metallurgical factors affecting transition temperature; Temper Embrittlement.

Fracture: Elementary theories of fracture. Griffiths theory of brittle fracture, ductile fracture.

Fatigue testing: Significance of fatigue test, stress cycles, S-N curve, fatigue limit, mechanism of fatigue failure, effect of stress concentration, size, surface condition and environments on fatigue, effect of metallurgical variables on fatigue properties.

Creep testing: The creep curve, creep properties of metals. Stress-rupture test, deformation and fracture at elevated temperature, theories of creep. Prediction of long time properties. Creep resistant materials. Effect of metallurgical variables on creep.

Text Books:

1. George E. Dieter, Mechanical Metallurgy, 3rd Edition, McGraw Hill, New York, 2013.
2. Norman E. Dowling, Mechanical Behavior of Materials, 2nd Edition, Prentice-Hall, Upper Saddle River, New Jersey, 1999
3. Thomas H. Courtney, Mechanical Behavior of Materials, 2nd Edition, McGraw Hill, New York, 2000.
4. M.A. Meyers and Chawla K, Mechanical Behavior of Materials, 2nd Edition, Cambridge University Press, 2009
5. C. Suryanarayana, Experimental Techniques in Materials and Mechanics, CRC press, 2011

MM303	Powder Metallurgy	PCC	3-0-0	3 Credits

Pre-requisites: None

Course Outcomes: At the end of the course, student will be able to:

CO1	Explain powder production techniques.
CO2	Describe the characterization techniques of the metal powders.
CO3	Discuss powder shaping techniques.
CO4	Explain the stages of sintering and influence of sintering atmospheres.
CO5	Discuss case studies on processing of industrial components.

Course Articulation Matrix:

CO \ PO/PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	S	-	-	-	L	-	-	-	-	-	-	-	M	-	-	-
CO2	-	-	-	M	M	-	-	-	-	-	-	-	-	-	-	M
CO3	S	-	-	-	L	-	-	-	-	-	-	-	S	-	-	-
CO4	S	M	S	`	-	-	-	-	-	-	-	-	S	-	-	-
CO5	-	-	-	S	-	-	-	-	-	S		S	M	-	-	-

S: Strong correlation, M: Medium correlation, L: Low correlation

Syllabus:

GENERAL CONCEPTS:

Introduction and History of Powder Metallurgy (P/M), Past, Present and Future Trends of P/M

POWDER PRODUCTION TECHNIQUES:

Mechanical, Chemical and Electrochemical methods, Atomisation and other emerging processes, High energy ball milling, mechanical alloying and applications, self-propagating high temperature synthesis. Performance Evaluation of different Processes, Design and Selection of Process.

CHARACTERISTICS OF POWDER:

Particle Size, Shape, Distribution and morphology, Tap density, green density, Interparticle Friction, flowability and surface Area, Particle porosity. Compressibility, pyrophorosity and toxicity.

POWDER SHAPING:

Blending and mixing of powders-equipment, Lubricants & Binders, Particle Packing Modifications. Powder Compaction: die compaction, process variables, density distribution during compaction, Isostatic Pressing, Cold and hot isostatic pressing, Injection Molding, Powder Extrusion, Slip Casting, Tape Casting, Analysis of Defects of Powder Compact, Introduction to additive manufacturing and applications, Powder Coating.

SINTERING:

Theory of Sintering, Sintering mechanisms, Sintering Variables, Sintering furnaces and atmospheres, Pressureless sintering, Liquid Phase Sintering, and Sintering of Single & Mixed Phase Powders. Modern Sintering Techniques: spark plasma sintering, microwave sintering, Laser Engineering Net Shaping (LENS), Structure-Property Correlation Study, Defects Analysis of Sintered Components.

APPLICATIONS OF POWDER METALLURGY:

Filters, Tungsten Filaments, Self-Lubricating Bearings, Porous Materials, ODS Alloys, Biomaterials and Case Studies.

Text Books:

1. R. M. German, Powder Metallurgy & Particulate Materials Processing, MPIF USA, 2005.
2. A. Upadhyaya and G S Upadhyaya, Powder Metallurgy, Universities Press, 2011.
3. J. S. Hirschhorn: Introduction to Powder Metallurgy, American Powder Metallurgy Institute, 1976.
4. P. C. Angelo and R. Subramanian: Powder Metallurgy- Science, Technology and Applications, Prentice-Hall India, 2008

MM304	Metal Joining	PCC	3-0-0	3 Credits

Pre-requisites: ME101-Basic Mechanical Engineering

Course Outcomes: At the end of the course, student will be able to:

CO1	Classify and differentiate welding processes
CO2	Explain heat flow in welding
CO3	Identify various defects and remedial measures in weldment
CO4	Appreciate the importance of welding metallurgy.

Course Articulation Matrix:

CO \ PO/PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	S	-	M	-	-	-	-	-	-	-	-	-	M	-	L	L
CO2	S	-	-	-	-	-	-	-	-	-	-	-	-	M	-	-
CO3	S	-	-	-	-	-	-	-	-	-	-	-	L	-	-	L
CO4	M	-	-	-	-	-	-	-	-	-	-	-	-	M	-	-

S: Strong correlation, M: Medium correlation, L: Low correlation

Syllabus:

Metal joining: Introduction to metal joining, welding, brazing, soldering., Weld joint design, Types of Welding-

Fusion Welding: Gas welding, Oxyacetylene Welding, Types of flames, process description and application, Arc welding, Heat sources & Arc characteristics, Shielded Metal Arc Welding, Gas–Tungsten Arc Welding, Plasma Arc Welding, Gas–Metal Arc Welding, Flux-Core Arc Welding, Submerged Arc Welding, Electro Slag Welding, Resistance Welding, Spot, Seam, Projection, Flash Butt-Welding, High-Energy Beam Welding - Electron Beam Welding, Laser Beam Welding,

Solid state welding: Diffusion, Ultrasonic, Explosion, Friction and Friction Stir Welding.

Welding Defects: Defects in welding, Concepts of Residual Stresses, Distortion, Remedies. Weldability Tests.

Welding Metallurgy: Introduction to Welding Metallurgy, Basic Solidification, Post-Solidification Phase Transformations, Microstructures in Different Zones of Welding,

Text Books:

1. N.K.Srinivasan, Welding Technology, Khanna publishers, 2008.
2. Sindo Kou, Welding metallurgy, John Willey, 2003, 2^{nd} Edition, USA.
3. J.F. Lancaster, Metallurgy of Welding, Abington Publishing, 6th edition, England. 1999.
4. Richard Little, Welding and Welding Technology, McGraw Hill, 1^{st} Edition, 2001.
5. Metals Handbook-Welding, Brazing and Soldering, American Society for Metals, 10th edition, Volume 6, USA, 1993.
6. Welding handbook, American Welding Society, 8th edition, vol.1 & 2, USA, 1987.
7. Inspection and testing of weld joints Welding handbook, American Welding Society, 7th edition, USA, 1983.
8. Metals Handbook-mechanical testing and evaluation, American Society for Metals, Volume 8, USA, 1993.

MM305	Mechanical Behaviour of Materials Laboratory	PCC	0-0-3	2 Credits

Pre-requisites: None

Course Outcomes: At the end of the course, student will be able to:

CO1	Operate mechanical testing equipment for measuring materials properties
CO2	Analyse the data from mechanical testing.
CO3	Understand the behavior of materials during various kinds of mechanical loading

Course Articulation Matrix:

CO \ PO/PSO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2	PSO 3	PSO 4
CO1	-	-	-	-	S	-	-	-	M	-	-	-	-	-	-	S
CO2	-	M	-	-	S	-	-	-	M	-	-	-	-	-	-	S
CO3	S	-	-	-	S	-	-	-		-	-	-	-	-	-	S

S: Strong correlation, M: Medium correlation, L: Low correlation

Syllabus

1. To determine the hardness of steel / aluminum / copper alloy using Vickers, Brinell and Rockwell testing systems.
2. To determine impact strength of steel / aluminum / copper alloy using Charpy and Izod Testing.
3. To determine tensile behavior of steel / aluminum / copper alloy using Universal Testing Machine.
4. To determine fatigue life from S-N curve using fatigue testing machine
5. To determine Creep curve and stages of creep using creep machine

Text Books:

1. Mechanical Behaviour of Materials Laboratory Manual
2. C. Suryanarayana, Experimental Techniques in Materials and Mechanics, CRC press, 2011

MM306	Powder Metallurgy Laboratory	PCC	0-0-3	2 Credits

Pre-requisites: None

Course Outcomes: At the end of the course, student will be able to:

CO1	Synthesize metallic and ceramic powders.
CO2	Determine the characteristics of powders.
CO3	Produce powder compacts and determine physical characteristics of green compact.
CO4	Sinter the compacts in controlled atmosphere.

Course Articulation Matrix:

CO \ PO/PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	S	-	-	-	M				M		-	-	-	-	M	-
CO2	M	-	-	-	S	-	-	-	-		-	-	-	-	-	M
CO3	M	-	-	-	S	-	-	-	-		-	-	-	-	S	-
CO4	M	-	-	-		-	-	-	-		-	-	-	-	S	-

S: Strong correlation, M: Medium correlation, L: Low correlation

Syllabus:

1. To determine Apparent Density, Tap Density and Flowability of various powders using Hall-Flow meter.
2. To study the concept of mechanical milling and mechanical alloying using planetary ball mill.
3. To study the compaction of elemental, as milled, ductile and brittle powders using die compaction machine.
4. To study the sintering behavior of ferrous, non-ferrous and / or ceramic powder compacts
5. To study structure property correlation of compacted and / or sintered samples.

Text Books:

1. Powder Metallurgy Laboratory Manual
2. Sintering Theory and Practice, R. M. German, New York, Wiley-VCH 1996
3. ASM Hand Book, ASM International, Vol: 7: Powder Metallurgy.

MM340	Introduction to Materials Science and Engineering	OPC	3-0-0	3 Credits

(Not offered to students of Metallurgical and Materials Engineering)

Pre-requisites: None

Course Outcomes: At the end of the course, student will be able to:

CO1	Discuss the characteristics and applications of metals and alloys, ceramics, polymers, composites
CO2	Explain different fabrication techniques of materials
CO3	Correlate the microstructure, properties, processing and performance of materials.
CO4	Select suitable materials for desired applications

Course Articulation Matrix:

CO \ PO/PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	S	-	M	-	-	-	-	-	-	-	-	-	M	-	L	L
CO2	S	-	-	-	-	-	-	-	-	-	-	-	-	M	-	-
CO3	S	-	-	-	-	-	-	-	-	-	-	-	L	-	-	L
CO4	M	-	-	-	-	-	-	-	-	-	-	-	-	M	-	-

S: Strong correlation, M: Medium correlation, L: Low correlation

Syllabus:

CLASSES OF MATERIALS:

Metals and alloys, oxide and non-oxide ceramics, polymers, and composites, Materials Paradigm – relation between processing, structure, properties, and applications of materials

STRUCTURE OF MATERIALS:

Atomic structure and interatomic bonding, Different levels of structure in materials, Polycrystalline, amorphous, and single crystalline materials; Partial crystallinity, Texture or crystallographic orientation of materials, Isotropy and anisotropy, Crystal structure of metals, alloys, and ceramics; Polymer structures, Crystal defects and imperfections in materials, Phase diagrams, Allotropy, Polymorphism, Polytypism.

PROPERTIES OF MATERIALS:

Thermal properties: Heat capacity, Thermal expansion, Thermal conductivity, Thermal stresses

Mechanical properties: Elastic and plastic deformation, stress, strain, tension, compression, shear force, hardness, rigidity, strength, ductility, malleability, fatigue, creep, fracture and failure of materials

Optical properties: Reflection, Refraction, Absorption, Transmission, Opacity and Translucency Luminescence, Photoconductivity

Electrical properties: electrical conduction and resistance, semiconductivity, dielectric behavior

Magnetic properties: magnetism, types of magnetism, magnetic moment, magnetic dipoles, magnetic field strength, magnetic induction, magnetization, permeability, susceptibility

APPLICATIONS OF MATERIALS:

Structural, functional, and biomedical applications

Text Books:

1. W.J. Callister, Materials Science and Engineering: An Introduction, Wiley, 2010
2. W.F.Smith, Foundations of Materials Science and Engineering, Tata McGraw Hill, 2008
3. D.R. Askeland, Essentials of Materials Science and Engineering, Cengage, 2013
4. J.F. Shackelford, Introduction to Materials Science for Engineers, Pearson, 2015
5. V Raghavan, Materials Science and Engineering – A first course, PHI Publications, 2011

MM351	Corrosion Engineering	PCC	3-0-0	3 Credits

Pre-requisites: CY101-Engineering Chemistry

Course Outcomes: At the end of the course, student will be able to:

CO1	Explain the principles of corrosion.
CO2	Evaluate corrosion mechanisms from first principles.
CO3	Suggest suitable techniques for corrosion monitoring and its prevention.
CO4	Discuss the case studies of critical materials.

Course Articulation Matrix:

CO \ PO/PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	S	-	-	-	-	-	-	-	-	-	-	-	-	M	-	-
CO2	M	-	-	-	-	-	-	-	-	-	-	-	-	M	-	-
CO3	M	M	-	-	M	-	-	-	-	-	-	-	-	M	-	-
CO4	S	-	-	-	-	-	-	-	-	-	-	-	-	M	-	-

S: Strong correlation, M: Medium correlation, L: Low correlation

Syllabus:

Principles of Corrosion: Introduction, Thermodynamics & Kinetics: Galvanic and EMF Series, Pourbaix Diagrams, Exchange Current Density, Passivity, Evans Diagram, Flade Potential.

Forms of Corrosion: Uniform, Galvanic, Pitting, Crevice, Intergranular Corrosion, Stress Corrosion Cracking, Corrosion Fatigue, Dealloying, high Temperature Oxidation-Origin and Mechanism, erosion.

Corrosion Testing and Monitoring: Weight Loss Method, Electrochemical Methods: Tafel extrapolation, linear polarization and Electrochemical Impedance Techniques.

Corrosion Prevention: Materials selection, Alteration of Environment, Design, Inhibitors, Cathodic and anodic protection, Coatings.

Case Studies: Specific case studies of corrosion in advanced and critical materials.

Text Books:

1. M G Fontana, N D Greene, Corrosion Engineering, McGraw Hill, New York, 1967.
2. EinarBardal, Corrosion and protection, Springer, 2004.
3. ZakiAhamad, Principles of Corrosion Engineering and Corrosion Control, Elsevier, 2006.
4. ASM Metal Hand book, Vol 13A- Corrosion-Fundamentals Testing & Protection, ASM, 2004.

MM352	Metal Forming	PCC	3-0-0	3 Credits

Pre-requisites: MM302-Mechanical Behaviour of Materials

Course Outcomes: At the end of the course, student will be able to:

CO1	Describe deformation behaviour and yield criteria in metal working.
CO2	Discuss hot working, cold working and annealing phenomena.
CO3	Differentiate metal forming processes.
CO4	Classify defects in formed products and suggest suitable remedial measures

Course Articulation Matrix:

PO/PSO CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	S	M	S	-	-	-	-	-	-	-	-	L	-	M	-	-
CO2	S	M	-	-	-	-	-	-	-	-	-		M	-	-	M
CO3	S	-	-	-	-	-	-	-	-	-	-	-	M	M	-	-
CO4	S	-	-	-	-	-	-	-	-	-	-	-	-	M	-	L

S: Strong correlation, M: Medium correlation, L: Low correlation

Syllabus:

INTRODUCTION:

Plane Stress Conditions, Review of two-dimensional stress and strain, state of stress in three dimensions, Stress tensor, Invariants, Mohr's circle for 3-dimensional state of stress, strain at a point Mohr's circle for strain, Hydrostatic & Deviatory components of stress, Elastic stress strain relations.

ELEMENTS OF THEORY OF PLASTICITY:

Flow curve, True stress & true strain, Yield criteria for ductile metals, Von Misses & Tresca yield criteria, combined stress tests. The yield locus, Anisotropy in yielding, Classification of forming processes variables in metal forming and their optimization, Flow stress determination, Cold working, Hot working, Strain rate effect, Friction and lubrication, Deformation zone geometry, Workability, Residual stresses.

FORGING:

Classification of Forging Processes, Forging Equipment, Forging in Plane Strain, Open- Die Forging, Closed-Die Forging, Calculation of Forging Loads in Closed-Die Forging, Forging Defects, Residual Stresses in Forgings

ROLLING:

Classification of Rolling Processes, Rolling Mills, Hot-Rolling, Cold-Rolling, Rolling of Bars and, Shapes, Forces and Geometrical Relationships in Rolling, Simplified Analysis of Rolling Load: Rolling Variables, Problems and Defects in Rolled Products, Rolling-Mill Control, Theories of Cold-Rolling, Theories of Hot-Rolling, Torque and Power

EXTRUSION:

Classification of Extrusion Processes, Extrusion Equipment, Cold Extrusion and Cold-Forming, Hot Extrusion, Deformation, Lubrication, and Defects in Extrusion, Analysis of the Extrusion Process, Hydrostatic Extrusion, Extrusion of Tubing, Production of Seamless Pipe and Tubing

DRAWING:

Introduction, Rod and Wiredrawing, Analysis of Wiredrawing, Tube-Drawing Processes, Analysis of Tube Drawing. Residual Stresses in Rods, Wires, and Tubes. Deep Drawing, Forming Limit Criteria, Defects in Formed Parts

Text Books:

1. G.E. Dieter, Mechanical Metallurgy, 3rd Edition, McGraw Hill, New York, 2013
2. Surender Kumar, Technology of Metal Forming Processes, PHI learning, 2008
3. William F. Hosford, Metal Forming - Mechanics and Metallurgy, Cambridge, 2011
4. Fritz Klocke, Manufacturing Processes, Volume 4, Forming, Springer, 2013 ·

MM353	Corrosion Engineering Laboratory	PCC	0-0-3	2 Credits

Pre-requisites: None

Course Outcomes: At the end of the course, student will be able to

CO1	Determine the EMFs of common metals.
CO2	Recognize galvanic corrosion.
CO3	Evaluate corrosion rate from Tafel plots.
CO4	Evaluate oxidation rate of metals and alloys

Course Articulation Matrix:

CO \ PO/PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	S	-	-	-	S	-	-	-	S	-	-	-	-	-	-	S
CO2	S	-	S	-	L	-	-	-	S	-	-	-	-	-	-	L
CO3	S	S	-	-	S	-	-	-	S	-	-	-	-	-	-	S
CO4	S	S	-	-	S	-	-	-	S	S	-	-	-	-	-	S

S: Strong correlation, M: Medium correlation, L: Low correlation

List of Experiments

1. Determination of EMFs of common metals.
2. Carryout Polarization Studies by using electrochemical workstation.
3. Evaluation of corrosion rate through Tafel plots.
4. Galvanic corrosion of copper-steel couple.
5. Stress-Corrosion Cracking of Steels.
6. Carry out Impedance studies by electrochemical workstation.
7. Determination of corrosion rate by weight loss measurements.
8. Find out rate of oxidation of alloys at high temperature.

Reference Book:

1. Corrosion Laboratory manual

MM361	Theory of Metallurgical Processes	DEC	3-0-0	3 Credits

Pre-requisites: MM202-Principles of Extractive Metallurgy,
MM203-Metallurgical Thermodynamics and Kinetics

Course Outcomes: At the end of the course, student will be able to:

CO1	Explain the techniques of extraction of metals
CO2	Apply thermodynamics and kinetics to pyro-, hydro-, and electro-metallurgical processes.
CO3	Correlate the phase diagrams to metallurgical processes.
CO4	Design and solve problems in extraction and refining of metals.

Course Articulation Matrix:

CO \ PO/PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	S	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-
CO2	S	M	-	-	-	-	-	-	-	-	-	-	M	M	-	-
CO3	S	M	-	-	-	-	-	-	-	-	-	-	-	M	-	-
CO4	S	S	S	-	-	-	-	-	-	-	-	-	S	M	-	-

S: Strong correlation, M: Medium correlation, L: Low correlation

Syllabus:

INTRODUCTION:
Introduction to different metallurgical processes and the importance of thermodynamic and kinetic aspects of the processes, Principles involved in pyro metallurgical, hydrometallurgical and electrometallurgical processes. Introduction to rate controlling mechanisms in extraction processes

THERMODYNAMIC PRINCIPLES:
Gibbs phase rule and its applications to multicomponent and multiphase reactions and to the construction of different stability diagrams; construction of different types of stability diagrams including phase diagrams. Alternative standard states (Roaultian and Henrian); interaction coefficients, their determination, and their applications in iron and steelmaking; quadratic solution model; regular solutions. Kinetics of thermally activated processes

REACTION EQUILIBRIA:
Solid- Liquid, liquid-liquid, and Gas-liquid reactions, homogeneous and heterogeneous reactions,

Interfacial phenomena, Gibbs adsorption isotherm; thermodynamics of interfaces/curved surfaces. Nonisothermal kinetics; reduced time plots for different kinetic models. Gas diffusion in porous media: molecular and Knudsen diffusion. Nucleation and growth.

PYROMETALLURGICAL PROCESSES:
Thermodynamics and Kinetics of Roasting; Predominance Area diagrams; structure and properties of slag; Role of slag, Kinetics of formation of slag; Ellingham diagrams, Oxidation-reduction reactions

Thermodynamics of iron and steel making: Physical Chemistry of Blast Furnace Reactions, Thermodynamics of Fe-O, C-O, and Fe-C-O systems and their applications to the blast furnace and steelmaking reactions.

HYDROMETALLURGICAL PROCESSES:
Principles of Leaching and recovery; Chemical reactions in leaching; Pourbaix diagrams; Leaching Kinetics; Arrhenius Reaction for reaction rate; Debye-Huckel law

ELECTROMETALLURGICAL PROCESSES:
Faraday’s laws; Reactions involved in Electrolytic cell; Kinetics of Electrode processes

Text Books:

1. David R Gaskell, Introduction to Metallurgical Thermodynamics, CRC Press, 2017
2. H.S. Ray and S.K. Ray, Kinetics of metallurgical processes, Springer, 2018.
3. M. Shamsuddin, Physical chemistry of metallurgical processes, Wiley, 2016
4. H.S. Ray and A. Ghosh, Principles of Extractive Metallurgy, New Age International, 2010
5. A. Ghosh and A. Chatterjee. Iron making and steelmaking: theory and practice. PHI Learning, 2008.

MM362	Fuels and Refractories	DEC	3-0-0	3 Credits

Pre-requisites: None

Course Outcomes: At the end of the course, student will be able to:

CO1	Classify the fuels and refractories and understanding their operating conditions.
CO2	Describe the production of solid, liquid and gaseous fuels.
CO3	Illustrate the production, composition, properties, testing and applications of refractories.
CO4	Select appropriate fuels and refractories to minimize the overall cost of production for a given application.

Course Articulation Matrix:

CO \ PO/PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	S	-	L	-	-	-	-	-	-	-	-	-	L	-	-	-
CO2	S	-		-	-	-	-	-	-	-	-	-	L	-	-	-
CO3	-	-	S	-	-	-	-	-	-	-	S	-	M	-	-	-
CO4	M	-	-	-`	M	-	-	-	-	-	-	-	-	-	-	M

S: Strong correlation, M: Medium correlation, L: Low correlation

Syllabus

FUELS:

Introduction to fuels technology, Conventional and newer sources of energy, Classification of fuels, Comparison of Fuels: Solid, liquid and gaseous fuels. Characterization of fuels: Analysis and calorific value with problems, Principles of conversion of fuels: Carbonization, Gasification and Hydrogenation, Principles of fuel combustion.

Solid fuels: origin, classification, preparation, properties, testing, and selection of coal and coke for use; Liquid fuels: sources, preparation, properties, testing, and applications of oil in industries; Gaseous fuels: sources (natural, prepared, and by-product), preparation, properties, testing, and applications of gaseous fuels.

REFRACTORIES:

Classification of refractories, their service properties, and applications; Manufacture of common refractory like silica, alumina, fireclay, dolomite, magnesite.

Selection of refractories: Selection of appropriate refractories for metallurgical applications such as coke ovens, Iron Blast furnace, LD and Copper convertors, soaking pits, Reheating furnaces and Heat Treatment furnaces.

Text Books:

1. J. D. Gilchrist, Fuels, Furnaces, and Refractories, Pergamon, 1977.
2. O.P. Gupta, Elements of Fuels, Furnaces and Refractories, Khanna Publishers, 1997.
3. R.C. Gupta, Fuels, Furnaces, and Refractories, Prentice-Hall India, 2016.

MM363	Mineral Processing	DEC	3-0-0	3 Credits

Pre-requisites: None
Course Outcomes: At the end of the course, student will be able to:

CO1	Explain the importance of mineral processing technology for metal extraction
CO2	Differentiate minerals beneficiation techniques
CO3	Discuss the theory of settlement of particles
CO4	Evaluate the recovery of mineral from the ore after concentration

Course Articulation Matrix:

CO \ PO/PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	S	-	-	-	-	-	-	-	-	-	-	-	M	-	-	-
CO2	S	M	-	-	-	-	-	-	-	-	-	-	M	-	-	-
CO3	1	-	-	-	-	-	-	-	-	-	-	-	-	**M**	-	-
CO4	S	M	-	-`	-	-	-	-	-	-	-	-	L	-	-	-

S: Strong correlation, M: Medium correlation, L: Low correlation

Syllabus:

INTRODUCTION:
Introduction to minerals processing: overview of mineral processing and its role in the extractive metallurgy industry. Sampling of ores by different methods – hand sampling, mechanical sampling, errors in sampling.

COMMINUTION OF MINERALS:

Theory of liberation of minerals, Crushing - primary, secondary and special crushers (jaw, gyratory, cone, rolls and toothed rolls crusher). Grinding – Types of grinding operations like Batch and Continuous grinding, Dry and Wet grinding, Open circuit and Closed circuit grinding, Grinding Mills – Ball mills, Theory of ball mill operation, Rod and Tube mills, Laws of comminution – Kick's, Rittinger's and Bond's theories.

SIZING AND CLASSIFICATION OF MINERALS:

Sizing: Study of laboratory sizing techniques and reporting of sizing data; Industrial sizing units - Types of screen surfaces, Grizzlies, TroDMMEls, Vibrating and Shaking screens; Movement of solids in fluids – Stokes' and Newton's laws, Terminal velocity and its relation with size, Relation between time and velocity, Relation between distance travelled and velocity; Equal settling ratio, Free and hindered settling ratios; Quantifying concentrating operations - Ratio of concentration, Recovery, Selectivity Index and Economic Recovery; Classification – Types of classifiers, Study of Settling Cones, Rake Classifier, Spiral Classifier and Cyclones.

CONCENTRATION OF MINERALS:

Heavy Media Separation – Principles, flowchart, different mediaused, Heavy Media Separation using heavy liquids and heavy suspensions, Washability curves for easy, normal and difficult coal; Thickening, filtration and its practice. Jigging– Theory of jigging, Jigging machines – Harz jig, Hancock jig, etc., Design considerations of a jig. Tabling – Study of stratification on a table. Shaking tables, Wilfley table. Tabling - Theory of flowing film concentration, shaking tables. Flotation – Principles of flotation, physical and chemical aspects, Factors affecting flotation, Classification of Collectors and Frothers, Regulators, and Factors affecting their efficiency, Application of flotation process for concentration of copper, lead and zinc ores; Principles and applications of magnetic and electrostatic separation processes.

Text Books:

1. Barry Wills and James Finch, Mineral Processing Technology, Elsevier, 2016
2. S. K. Jain, Minaeral Processing, CBS publishers, 2005.
3. S K Haldar - Mineral Exploration: Principles and Applications, Elsevier, 2019
4. CK Gupta - Chemical metallurgy:principles & practice, Wiley, 2003

MM364	Surface Engineering	DEC	3-0-0	3 Credits

Pre-requisites: MM251-Phase Transformations and Heat Treatment

Course Outcomes: At the end of the course, student will be able to:

CO1	Identify surface modification processes for industrial applications.
CO2	Describe the principles of surface modification processes and compare their advantages and limitations.
CO3	Select suitable testing methods to evaluate a modified surface.
CO4	Suggest suitable surface modification process to control wear, corrosion and oxidation.

Course Articulation Matrix:

CO \ PO/PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	S	L	M	-	-	-	-	-	-	-	-	-	-	M	-	L
CO2	S	-	-	-	-	-	-	-	-	-	-	-	-	M	-	L
CO3	S	-	M	-	M	-	-	-	-	-	-	-	-	-	-	S
CO4	S	-	M	-	-	-	-	-	-	-	-	-	-	-	-	L

S: Strong correlation, M: Medium correlation, L: Low correlation

Syllabus:

INTRODUCTION:

Purpose and scope of surface engineering; past, present and future status of surface engineering. Types of surface layers; Surface modification processes - classification; Substrates and their pre-treatments; Coatings and their characteristics; Single- and multi- layer coatings, Types of coatings and potential properties of coatings.

SURFACE ENGINEERING FOR WEAR AND CORROSION CONTROL:

Damage of the surfaces by corrosion and wear; Wear mechanisms and categories of wear; Methods to control wear and corrosion, Material/process selection.

SURFACE ENGINEERING TO CHANGE THE SURFACE METALLURGY:

Selective surface hardening - Flame and induction hardening, High energy beam hardening (electron and laser beam); Laser melting and shot-peening.

SURFACE ENGINEERING TO CHANGE THE SURFACE CHEMISTRY:

Diffusion coatings - Carburizing, Nitriding, Carbonitriding, Nitrocarburizing, Cyaniding, Pack-cementation (Aluminizing, Siliconizing, Chromizing, Boronizing,); Phosphate coatings, Chromate coatings, Anodizing, Micro Arc Oxidation; Oxidation Treatments; Plasma based surface modification processes; Ion- implantation and Laser alloying.

SURFACE ENGINEERING TO ADD A SURFACE LAYER OR COATING:

Organic coatings, ceramic coatings, Hot Dip coatings, Electroplating and electroless plating, Weld overlay coatings, Thermal spray coatings (Arc spray, plasma spray, Flame spray, HVOF, Detonation spray), Cold Spray, Cladding.

RECENT TRENDS IN SURFACE ENGINEERING:

Physical vapour deposition (PVD), Chemical vapour deposition (CVD), Evaporation, Sputtering, Ion plating. Use of Laser and plasma in surface engineering. Surface modification by directed energy beams. Surface modification by Friction stir processing: Surface composites. Nano-composite coatings/surfaces; Nano-engineered coatings, Diamond like coatings (DLC), Sol Gel coatings, Novelty of surface composition and microstructure, Specific industrial applications.

Text Books:

1. J. R. Davis, Surface Engineering for corrosion and wear resistance, ASM International, 2001
2. M. Kamaraj and V. M. Radhakrishnan, Basics of Surface Technology, New Academic Science, 2018
3. P. A. Dearnley, Introduction to Surface Engineering, Cambridge University Press, 2017
4. A. W. Batchelor, M. Chandrasekaran, N. L. Lo, Materials Degradation and Its Control by Surface Engineering, World Scientific, 2003

MM365	Advanced Manufacturing Processes	DEC	3-0-0	3 Credits

Pre-requisites: MM253-Casting and Solidification,
MM303-Powder Metallurgy, MM304-Metal Joining,
MM302-Mechanical Behaviour of Materials

Course Outcomes: At the end of the course, student will be able to:

CO1	Explain the need for advanced manufacturing techniques
CO2	Discuss various advances in manufacturing of metallic materials
CO3	Describe the principles, process and advantages of different advanced techniques
CO4	Apply the knowledge to selective

Course Articulation Matrix:

CO \ PO/PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	S	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-
CO2	S	-	-	-	-	-	-	-	-	-	-	-	M	-	-	-
CO3	S	-	M	-	-	-	-	-	-	-	-	-	M	-	-	-
CO4	-	M	-	-	-	-	-	-	-	-	-	-	-	-	M	-

S: Strong correlation, M: Medium correlation, L: Low correlation

Syllabus:

INTRODUCTION:

Overview of advances in manufacturing of metallic materials by casting, forming, joining

ADVANCED CASTING TECHNIQUES:

Rapid Solidification processing: Introduction to processing of amorphous metals, Principles of Rapid Solidification Processing, General Techniques to Achieve High Rates of Solidification, Melt Spinning, Bulk Metallic Glasses - Flux Melting Technique, Role of Contamination, Bulk Metallic Glass Casting Methods - Water-Quenching Method, High-Pressure Die Casting, Copper Mold Casting, Cap-Cast Technique, Suction-Casting Method, Squeeze-Casting Method, Arc-Melting Method, Unidirectional Zone-Melting Method, Electromagnetic Vibration Process.

ADVANCED FORMING TECHNIQUES:

Severe plastic deformation (SPD): Applications of Ultrafine-Grained and Nanograined Metals, Basic Principles of SPD Methods, Difference between SPD and Conventional Metal-Forming

Processes, Grain Refinement Mechanisms under SPD conditions - FCC metals, HCP metals, SPD methods for bulk samples - Equal-Channel Angular Pressing (ECAP) and High-Pressure Torsion (HPT), Mechanical Properties of Ultrafine-Grained and Nanostructured Metals

ADVANCED JOINING TECHNIQUES:

Friction Stir Welding (FSW): Solid State Welding, Friction Stir Welding, Comparison of FSW to other welding processes, Taxonomy for Friction Stir Welding and Processing, Overall Applicability of FSW, Macroscopic Processes during FSW, Heat Generation during Friction Stir Process, Heat Generation from Frictional Heating, Heat Generation from Plastic Deformation, Heat Transfer During Friction Stir Process, Material Flow during FSW, Welding tools used for FSW, Parameter effects, Materials used with FSW, Joint geometries, Joint preparation, Post-weld heat treatment, FSW of Al, Mg and Ti alloys.

ADDITIVE MANUFACTURING TECHNIQUES:

Selective laser melting: Introduction - Distinction between SLM and traditional methods, Processing strategy, Microstructure, Defect characteristics, Performance and application; Characteristics and selection of materials - Powder stacking characteristics, Powder fluidity, Oxygen content, Laser absorption rate of powder; Principles of selective laser melting - Laser energy transfer, Dynamics of molten pool, Stability of molten pool, Metallurgical characteristics of selective laser melting – Balling, Porosity, Cracking, Oxidation, Loss of alloying elements, Solidification microstructure characteristics, Processing of metals and metal matrix composites.

Text Books:

1. C. Suryanarayana and A. Inoue, Bulk Metallic Glasses, CRC press, 2017
2. G. Faraji, H. S. Kim and H. T. Kashi, Severe Plastic Deformation: Methods, Processing and Properties, Elsevier, 2018
3. R. S. Mishra, P. S. De, N. Kumar, Friction Stir Welding and Processing: Science and Engineering, Springer 2014
4. Bo Song and Shifeng Wen, Selective Laser Melting for Metal and Metal Matrix Composites, Elsevier, 2021
5. A. Gebhardt, “Rapid prototyping”, Hanser Gardener Publications, 2003.
6. L.W. Liou and F.W. Liou, “Rapid Prototyping and Engineering applications: A tool box for prototype development”, CRC Press, 2007.
7. A.K. Kamrani and E.A. Nasr, “Rapid Prototyping: Theory and Practice”, Springer, 2006.
8. P.D. Hilton and P.F. Jacobs, “Rapid Tooling: Technologies and Industrial Applications”, CRC press, 2000.
9. Ian Gibson, David W Rosen, Brent Stucker., “Additive Manufacturing Technologies: Rapid Prototyping to Direct Digital Manufacturing”, Springer, 2010
10. D.T. Pham, S.S. Dimov, Rapid Manufacturing: The Technologies and Applications of Rapid Prototyping and Rapid Tooling, Springer 2001.

MM366	Metallurgical Waste Recycling	DEC	3-0-0	3 Credits

Pre-requisites: MM202-Principles of extractive metallurgy,
MM252-Non-ferrous extractive metallurgy,
MM301-Iron and Steel making

Course Outcomes: At the end of the course, student will be able to:

CO1	Identify types and sources of metallurgical waste.
CO2	Discuss the impact of metallurgical waste on economics and environment
CO3	Suggest ideas for conservation of energy in metallurgical processes.
CO4	Comprehend recycling of metallurgical waste.

Course Articulation Matrix:

CO \ PO/PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	M	-	-	-	-	L	M	-	-	-	-	-	L	-	-	-
CO2	M	-	-	-	-	S	S	-	-	-	-	-	L	-	-	-
CO3	M	-	-	-	-	M	M	-	-	-	-	-	L	-	-	-
CO4	M	-	-	-	-	L	M	-	-	-	-	-	L	-	-	-

S: Strong correlation, M: Medium correlation, L: Low correlation

Syllabus:

INTRODUCTION:

Types of Metallurgical waste, Waste characterization, Energy conservation, Environmental issues, recycling, etc.

METALLURGICAL WASTES:

Primary and secondary solid wastes in metallurgical and powder industry, Generation of waste during primary processing of ores and beneficiation, Waste from extraction and refining processes, Nuclear waste, Gaseous wastes in metallurgical operations, minimization techniques, precautionary measures

ENERGY SAVING:

Alternative routes of extraction of metals for energy saving. Direct reduction v/s Conventional route for steel making. Role of optimal selection of metal processing route. Conservation through protection of materials against decay, Waste heat recovery methods

ENVIRONMENTAL PROTECTION:

General concepts of environment, toxicology of metals, Stack gases of Electric Arc Furnaces and primary metal production processes, and methods for their beneficiation

RECYCLING OF METALS:

Economical, technological and environmental aspects of metal recycling (ferrous/non-ferrous), Economic uses of solid waste such of B.F. slag and fly ash & wastes from non-ferrous industry, Case study: Recycling of ferrous/non-ferrous metals, scraps, cans, cables, wires, electronics and computers waste

Text Books:

1. R.C. Gupta, Energy and environmental management in metallurgical industries, Prentice-Hall India, 2012
2. S. Ramachandra Rao, Resource recovery and recycling from metallurgical wastes, Elsevier, 2011
3. L. K. Wang, N. K. Shammas, Y.T Hung, Waste Treatment in the Metal Manufacturing, Forming, Coating, and Finishing Industries, CRC press, 2016
4. S. Ndlovu, G. S. Simate, E. Matinde, Waste Production and Utilization in the Metal Extraction Industry CRC press, 2017
5. Clyde S. Brooks , Metal Recovery from Industrial Waste, CRC press, 2018

MM390	Fundamentals of Materials Processing Technology	OPC	3-0-0	3 Credits

Not offered to students of Metallurgical and Materials Engineering)

Pre-requisites: None

Course Outcomes: At the end of the course, student will be able to:

CO1	Describe various product forms of engineering materials
CO2	Discuss appropriate material processing techniques
CO3	Explain principles involved in different processing methods
CO4	Select suitable processing technique for a given material and application

Course Articulation Matrix:

CO \ PO/PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	M	-	-	-	-	L	M	-	-	-	-	-	L	-	-	-
CO2	M	-	-	-	-	S	S	-	-	-	-	-	L	-	-	-
CO3	M	-	-	-	-	M	M	-	-	-	-	-	L	-	-	-
CO4	M	-	-	-	-	L	M	-	-	-	-	-	L	-	-	-

S: Strong correlation, M: Medium correlation, L: Low correlation

Syllabus

CLASSIFICATION OF MATERIALS AND PRODUCTS:

Metals and alloys, oxide and non-oxide ceramics, polymers, and composites; various forms of engineering materials as consumer products and their applications

METAL CASTING AND CERAMIC FORMING:

Overview of casting technology, melting and pouring, solidification and casting of metals, casting defects, casting quality, Forming of ceramics by slip casting, pressure casting, gel casting, tape casting.

MECHANICAL FORMING AND SHAPING:

Overview of metal forming, friction and lubrication in metal forming, bulk deformation processes of metals - rolling, forging, extrusion, drawing, sheet metal forming; extrusion and injection molding of ceramics

POWDER PROCESSING AND SINTERING:
Characteristics of powders, processing of metallic and ceramic powders, production of bulk products and design considerations, conventional pressing and sintering methods, alternative pressing (CIP, HIP) and sintering (microwave, spark plasma) techniques.

THIN FILMS AND COATINGS:

Films – Physical and chemical vapour deposition techniques including molecular beam epitaxy, laser ablation and hot wire and microwave CVD techniques. Coatings – dry and wet deposition techniques including electro-deposition, spin coating, sol-gel, Spray drying, Doctor blade technique, ink printing, etc;

Text Books:

1. S. Kalpakjian, S. R. Schmid, Manufacturing Engineering and Technology, Pearson, 2014
2. Vukota Boljanovic, Metal Shaping Processes - Casting and Molding, Particulate Processing, Deformation Processes, and Metal Removal, Industrial Press, 2010
3. Phillip Boch, Ceramic Materials - Processes, Properties, and Applications, Wiley, 2010
4. James S. Reed, Principles of Ceramics Processing, Wiley, 1995
5. D.L. Smith, Thin-film deposition: principles and practice, McGraw Hill, 1995

SM355	**Engineering Economics and Management**	**HSC**	**3-0-0**	**3 Credits**

Course outcomes: At the end of the course, the student will be able to:

CO1	Evaluate the economics of the management, operation, and growth and profitability of engineering firms and analyze operations of markets under varying competitive conditions
CO2	Analyze cost/revenue data and carry out economic analyses in the decision making process to justify existing/finding alternative projects on an economic basis
CO3	Produce a constructive assessment of a social problem by drawing the importance of environmental responsibility and demonstrate knowledge of global factors influencing business and ethical issues.
CO4	Apply models to describe economic phenomena; analyze and make predictions about the impact of government intervention and subsequent changing market conditions on consumer-producer relationship

Detailed syllabus

General Foundations of Economics: Forms of organizations-Objectives of firms-Opportunity Principle-Discounting-Production possibility frontier-Central problems of an economy- Two sector, three sector, and four sector circular flow of income-Demand Analysis-Individual, Market and Firm demand- Determinants of demand and supply- Shifts and changes in demand and supply- Market equilibrium, Shortages versus surpluses- Elasticity of demand and business decision making

Production functions in the short and long run-Cost concepts- short run and long run costs-economies and diseconomies of scale--Product markets- Market Structure-Competitive market-Imperfect competition (Monopoly, Monopolistic competition and Oligopoly) Price discrimination-Game Theory--Maximin, Minimax, Saddle point, Nash Equilibrium, Prisoners' Dilemma-Monetary system-Indian stock market- Development Banks-NBFIs- role of Reserve Bank of India, Money Market, Capital market; NIFTY, SENSEX.

Brief introduction to data analytics as a tool in terms of understanding the markets, performances of indexes, performance of various sectoral indexes.

Introduction to Management Theory and Functional Areas-Marketing-HR and Finance-Financial Mangement-Financial Statements-Profit and Loss Statements-Fund Flow Statement-Balance Sheets-Ratio Analysis-Investment and Financial Decision—Inventory Management-Functions and Objectives of Inventory Management—Decision Models-Break even analysis-Economic Order Quantity (EOQ)-Model Sensitivity Analysis of EOQ model.

Text Books:

1. K. E. Case, R. C. Fair and S. Oster, *Principles of Economics*. Prentice Hall, 10th ed., 2011.
2. Maheswari, Anil. *Data Analytics*. Mc Graw Hill, 2017
3. N. G. Mankiw, *Principles of Microeconomics*. Cengage Publications,7th ed.,2014.
4. P.A. Samuelson and W.D Nordhaus. *Economics*. Tata Mcgraw Hill, 19th Ed., 2017.
5. R.S. Pindyck, D.L. Rubinfield and P.L. Mehta, *Micro-economics*, Pearson Education, 9th Edition, 2018.
6. R.W.Griffin, *Management, Principles and Practices*. Cengage India,11th ed.,2017.
7. S. B. Gupta. *Monetary Economics: Institutions, Theory & Policy*, New Delhi: S. Chand & Company Ltd., 2013.

IV Year B.Tech Course Structure

MM401	Materials Characterization	PCC	3-0-0	3 Credits

Pre-requisites: PH101-Engineering Physics,
CY101-Engineering Chemistry,
MM201-Physical Metallurgy

Course Outcomes: At the end of the course, student will be able to:

CO1	Describe the principles of optical and electron microscopy.
CO2	Choose the suitable characterization techniques for microstructural and compositional analysis of materials
CO3	Demonstrate the Bragg's law of diffraction and the principle of XRD.
CO4	State the thermal analysis technique and apply them to determine various thermal events in materials.

Course Articulation Matrix:

CO \ PO/PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	S	-	-	-		-	-	-	-	-	-	-	-	-	-	M
CO2	S	S	-	-		-	-	-	-	-	-	-	-	-	-	M
CO3	S	-	-	-	S	-	-	-	-	-	-	-	-	-	-	S
CO4	S	-	-	-	M	-	-	-	-	-	-	-	-	-	-	M

S: Strong correlation, M: Medium correlation, L: Low correlation

Syllabus:

MICROSCOPY:

Optical microscopy: concepts of magnification, resolution, numerical aperture, depth of field, Optical image defects, principles of image formation by light, components of light optical microscope, applications of OM-grain size determination, sample preparation.

Electron microscopy: Comparison of OM, SEM and TEM, Basic design of SEM and TEM, working principles, Electron source, lens arrangement, Electron beam specimen interaction, image contrast, image defects, modes of imaging, Bright field image, dark field image, SAED, CBED, EBSD, Energy-dispersive X-ray spectroscopy (EDS), Wavelength-dispersive X-ray spectroscopy

(WDS), applications of SEM and TEM, sample preparation.

X-RAY DIFFRACTION:

Properties of X-rays, Production of X-rays, Diffraction, Bragg's law, X-Ray diffraction methods, XRD equipment, Indexing the XRD pattern, XRD applications: Phase identification, Phase mixtures and phase diagram, estimation of crystal size and lattice strain, Crystal structure determination, Precise lattice parameter measurements, Stress measurement.

THERMAL ANALYSIS TECHNIQUES:

Thermogravimetric analysis (TGA), Differential scanning calorimetry (DSC), Differential thermal analysis (DTA), Thermomechanical analysis (TMA) and Dynamic mechanical analysis (DMA)

Text Books:

1. P.J. Haines (eds.) – Principles of Thermal Analysis and Calorimetry, The Royal Society of Chemistry, 2002
2. B.D.Cullity and S.R.Stock, Elements of X-Ray Diffraction, 3rd Edition, Prentice Hall, NJ, 2001.
3. C. Suryanarayana and M. G. Norton X-Ray Diffraction: A Practical Approach, Springer, 1998
4. ASM Metallographer's Guide, ASM International, 2002.
5. C. Suryanarayana, Experimental Techniques in Materials and Mechanics, CRC press, 2011
6. P.R. Khangaonkar, An Introduction to Material Characterization, Penram publishing, 2010.
7. D. Brandon and W. D. Kaplan, Microstructural Characterization of Materials, Wiley, 2010
8. R. F. Egerton, Physical Principles of Electron Microscopy, Springer, 2016.
9. Transmission Electron Microscopy: A Textbook for Materials Science, Springer, 2009.

MM402	Computational Materials Engineering	PCC	3-0-0	3 Credits

Prerequisites: MA101-Mathematics,
CS101- Introduction to Algorithmic Thinking and Programming

Course outcomes: At the end of the course students will be able to:

CO1	Explain the importance of modelling and simulation in materials engineering
CO2	Apply explicit and implicit methods to solve diffusion problems
CO3	Use atomistic computational materials tools to model, understand, and predict the properties of real materials
CO4	Predict microstructural evolution using phase field method

Course Articulation Matrix:

CO \ PO/PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	S	S	-	-		-	-	-	-	-	-	-	M	-	-	-
CO2	S	S	-	-	M	-	-	-	-	-	-	-	M	M	-	-
CO3	-	S	M	-	M	-	-	-	-	-	-	-	-	S	-	-
CO4	-	-	S	-	M	-	-	-	-	-	-	-	-	S	-	-

S: Strong correlation, M: Medium correlation, L: Low correlation

Syllabus:

INTRODUCTION:
Introduction to Computation Materials Engineering, Modelling and simulation in materials engineering, brief overview of different modelling techniques, Length and time scales in materials in modelling.

THERMODYNAMIC MODELLING:
CALPHAD, ThermoCalc, alloy design, Materials selection and design, Phase equilibria and free energy calculations, Examples of CALPHAD for designing alloys (Iron-carbon phase diagram) and understanding the thermodynamics (property diagrams), Para-equilibrium

NUMERICAL METHODS:

Finite difference method for solving partial differential equations, Explicit and implicit techniques: their relative performance in terms of stability and accuracy, solving Fick's 2nd law to study the homogenization. Introduction to LAMMPS

MOLECULAR DYNAMICS and MONTE-CARLO METHODS:

Basics and applications, molecular modelling: interatomic potential, requirements for molecular dynamics simulation, Verlet algorithm. Molecular Dynamics (MD) simulations: Types of MD simulations, Types of potentials used in MD simulations, using MD simulations to predict melting point of pure metals, using Potts model (Monte Carlo simulation) to study abnormal grain growth,

MICROSTRUCTURE MODELLING:

Phase Field modelling, Introduction to the diffuse interface approach in microstructural modelling, conserved and non-conserved variables in phase field models, Cahn-Hilliard and Allen-Cahn equations, using phase field method to study spinodal decomposition, dendrite growth, precipitate growth etc.

Text Books:

1. Michael Heath, Scientific computing: An introductory survey, McGraw Hill, 2002
2. Dierk Raabe, Computational Materials Science, Wiley, 1998
3. Richard Lesar, Introduction to Computational Materials Science: Fundamentals to Applications, Cambridge University Press, 2013
4. W. Hegert, A. Ernst, M. Dane (Eds), Computational Materials Science, Springer, 2004
5. June Gunn Lee, Computational Materials Science-An Introduction, CRC Press, 2015
6. E. B. Tadmor and R. E. Miller, Modeling Materials (Continuum, Atomistic and Multiscale Techniques), Cambridge University Press, 2011

MM403	Materials for Automotive & Aerospace Applications	PCC	2-0-0	2 Credits

Pre-requisites: MM201-Physical Metallurgy

Course Outcomes: At the end of the course, student will be able to:

CO1	Evaluate materials with respect to material properties and manufacturing processes for a given design specification or application.
CO2	Understand and use the material selection criteria for different aerospace applications.
CO3	Explain the applications of steels, alloys, super alloys, ceramics and composites materials.
CO4	Evaluate the importance of high temperature materials and their characterization.

Course Articulation Matrix:

CO \ PO/PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	S	-	-	-	-	-	-	-	-	-	-	-	-	M	-	M
CO2	S	M	-	-	-	-	-	-	-	-	-	-	-	M	-	
CO3	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	M
CO4	S	M	L	-	-	-	-	-	-	-	-	-	-	M	-	

S: Strong correlation, M: Medium correlation, L: Low correlation

Syllabus:

INTRODUCTION TO AEROSPACE MATERIALS:

Perspectives and challenges in materials development, Evolution of materials research in aerospace, Materials processing facilities, State-of-the-art materials manufacturing and processing.

METALLURGICAL ALLOY REQUIREMENTS, DEVELOPMENT AND PROCESSING TECHNOLOGIES:

Steels, Maraging steels, ESR steels, Titanium alloys, Aluminum alloys, Permanent and soft Magnets including Sm-Co alloys, Superalloys, Cu-alloys, Bimetallic, Cast components, Additively manufactured components, Be-alloys, Zero thermo elastic coefficient alloys

SPECIAL MATERIALS, THEIR REQUIREMENTS AND DEVELOPMENT:

Introduction, Modern ceramic materials, Cermets, glass ceramic, Production of semi-fabricated forms, Carbon/Carbon composites, Fabrication processes and its aerospace applications involved in metal matrix composites, polymer composites.

HIGH TEMPERATURE MATERIALS CHARACTERIZATION:

Classification, production and characteristics, Methods and testing, Determination of mechanical and thermal properties of materials at elevated temperatures, Application of these materials in thermal protection systems of aerospace vehicles.

STANDARDS AND QUALITY CONTROL STANDARDS:

AS9100 series-based Quality Management System, ISO 9001, Operational risk management, Quality control and reliability, Materials selection, Materials inspection, Measurement, analysis & process improvement.

Text Books:

1. Adrian Mouritz, Introduction to Aerospace Materials, Woodhead Publishing, 2012.
2. Sam Zhang and Dongliang Zhao, Aerospace Materials Handbook, CRC Press, 2012.
3. Raghavan.V., "Materials Science and Engineering", Prentice Hall of India, New Delhi, 1993.
4. Sam Zhang, ‘Aerospace Materials Handbook (Advances in Materials Science and Engineering) 1st Edition, 2016.

MM404	Materials Characterization Laboratory	PCC	0-0-3	2 Credits

Pre-requisites: MM201-Physical Metallurgy

Course Outcomes: At the end of the course, student will be able to:

CO1	Quantify microstructural features using image analysis tool.
CO2	Observe the fracture surface and identify the mode of fracture.
CO3	Analyze the chemical composition of materials through SEM-EDS.
CO4	Determine phases and crystal structure of the material using XRD technique.
CO5	Determine the thermal properties of materials.

Course Articulation Matrix:

CO \ PO/PSO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2	PSO 3	PSO 4
CO1	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	S
CO2	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	S
CO3	-	S	-	-	S	-	-	-	-	-	-	-	-	-	-	S
CO4	-	-	S	-	S	-	-	-	-	-	-	-	-	-	-	S
CO5	-	-	3	-	S	-	-	-	-	-	-	-	-	-	-	S

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List of Experiments:

1. Image analysis of microstructures using OM.
2. Microstructural analysis using SEM, TEM
3. Fractography analysis using SEM
4. Chemical Analysis of phases through SEM/TEM-EDS
5. Determination of crystal structures, lattice parameter measurements, indexing and identification of phases using X-Ray Diffractometer
6. Oxidation kinetics using TGA / DTA.
7. Determination of thermal properties using DSC, TMA

Reference Books:

1. Materials Characterization Techniques Laboratory Manual

MM411	Metallurgical Failure Analysis	DEC	3-0-0	3 Credits

Pre-requisites: MM302-Mechanical Behaviour of Materials, MM353-Materials Characterization

Course Outcomes: At the end of the course, student will be able to:

CO1	Explain the importance of failure analysis in engineering components
CO2	Inspect and analyze the failed engineering components
CO3	Differentiate fracture modes and its failure mechanisms
CO4	Explain failures due to faulty practices
CO5	Examine failure analysis through case studies.

Course Articulation Matrix:

CO \ PO/PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	S	M	-	-	-	-	-	-	-	-	-	-	-	M	-	-
CO2	S	M	-	-	-	-	-	-	-	-	-	-	-	M	-	-
CO3	S	-	-	-	M	-	-	-	-	-	-	-	-	M	-	M
CO4	S	M	M	-	M	-	-	-	-	-	-	-	-	M	-	M
CO5	S	M	-	-	M	-	-	-	-	-	-	-	-	M	-	M

S: Strong correlation, M: Medium correlation, L: Low correlation

Syllabus:

Types of failures: Ductile, Brittle, Fatigue, Creep, Corrosion, Wear etc., Failure under Creep and Fatigue, Creep Fatigue Interaction, Mixed mode and Fatigue Failures, Failure Mechanisms, Embrittlement Phenomena, Environmental Effects, Failures due to Faulty Heat Treatments, Failures in Metal Forming and Welding.

Stages of Failure Analysis: Aim of Metallurgical Failure Analysis, Collection of Background Data & Selection of Samples, Preliminary Examination of Failed Part (Visual Examination and Record Keeping), Nondestructive Testing, Mechanical Testing, Selection, Presentation and Cleaning of Fracture Surface, Macroscopic Examination of Fracture Surface, Microscopic Examination of Fracture Surface. Life Estimation under Creep and Fatigue.

Case Studies: Prevention of Failures, Case Histories of Component Failures.

Text Books:

1. ASM Metals Hand Book, Failure Analysis and Prevention, Vol. 11, 10^{th} Edition, ASM International, 2002.
2. S. Suresh, Fatigue of Materials, 2nd Edition, Cambridge University Press, 1998.
3. Richard W. Hertzberg, Deformation and Fracture Mechanics of Engineering Materials, 5^{th} Edition, John Wiley & Sons, New York, 2012.

MM412	Non-Destructive Testing	DEC	3-0-0	3 Credits

Pre-requisites: PH101-Engineering Physics, MM201-Physical Metallurgy

Course Outcomes: At the end of the course, student will be able to:

CO1	Explain the working principles of non-destructive testing techniques
CO2	Compare and contrast NDT techniques
CO3	Select suitable NDT techniques for identification of defects in cast, formed and welded structures
CO4	Describe the advanced NDT techniques

Course Articulation Matrix:

CO \ PO/PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	S	L	L	-	M	-	-	-	-	-	-	-	-	-	-	M
CO2	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	L
CO3	S	M	M	-	M	-	-	-	-	-	-	-	-	-	-	S
CO4	S	-	-	-	M	-	-	-	-	-	-	-	-	-	-	M

S: Strong correlation, M: Medium correlation, L: Low correlation

Syllabus:

INTRODUCTION:

Manufacturing processes, Types of discontinuities associated with manufacturing processes, Defects in Metals and Alloys, Defects in Ceramics, Fracture Mechanics, and Life Cycle Prediction, Methods of visual, pressure and leak testing and underlying principles

ULTRASONIC TEST:

Principle of Wave Propagation, Reflection, Refraction, Diffraction, Mode Conversion and Attenuation, Sound Field, Piezo-electric Effect, Ultrasonic Transducers and their Characteristics, Ultrasonic Equipment and Variables Affecting Ultrasonic Test, Ultrasonic Testing, Interpretations and Guidelines for Acceptance, Rejection - Effectiveness and Limitations of Ultrasonic Testing.

LIQUID PENETRANT TEST:

Liquid Penetrant Test, Basic Concepts, Liquid Penetrant System, Test Procedure, Effectiveness and Limitations of Liquid Penetrant Testing,

EDDY CURRENT TEST:

Principle of Eddy Current, Eddy Current Test System, Applications of Eddy Current Testing Effectiveness of Eddy Current Testing

MAGNETIC PARTICLE TEST:

Magnetic Materials, Magnetization of Materials, Demagnetization of Materials, Principle of Magnetic Particle Test, Magnetic Particle Test Equipment and Test Procedure, Standardization and Calibration, Interpretation and Evaluation, Effective Applications and Limitations of the Magnetic Particle Test.

RADIOGRAPHY:

Principles of radiation, Industrial radiography techniques, Industrial radiography film processing, Safety and radiation protection

INDUSTRIAL APPLICATIONS OF NDT:

Span of NDT Activities in Railways, Nuclear, Non-nuclear and Chemical, Industries, Aircraft and Aerospace Industries, Automotive Industries, Offshore Gas and Petroleum Projects, NDT of pressure vessels, castings, welded constructions

Text Books:

1. Baldev Raj, Practical Non-destructive Testing, Wood head publishing limited, 2002
2. Ravi Prakash, Non-Destructive Testing Techniques, New Age International, 2010
3. J.B. Hull and Vernon John, Non-Destructive Testing, Macmillan, 2015
4. G. V. Crowe, An Introduction to Nondestructive Testing, American Society for NDT, 2009

MM413	Materials Selection and Design	DEC	3-0-0	3 Credits

Pre-requisites: MM201-Physical Metallurgy

MM302-Mechanical Behaviour of Materials

Course Outcomes: At the end of the course, student will be able to:

CO1	Review the criteria for materials selection
CO2	Discuss processing routes to achieve desired microstructure of materials
CO3	Describe heat treatment steps for modifying microstructure and mechanical properties.
CO4	Judge materials for structural, functional and bio applications

Course Articulation Matrix:

PO/PSO CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	S	-	-	-	-	-	-	-	-	-	-	L	-	-	M	-
CO2	S	-	-	-	-	-	-	-	-	-	-	-	-	M	-	-
CO3	S	-	-	-	-	-	-	-	-	-	-	-	-	-	M	-
CO4	S	-	M	-	-	-	-	-	-	-	-	-	-	-	M	-

S: Strong correlation, M: Medium correlation, L: Low correlation

Syllabus:

MATERIALS DESIGN:

Introduction to materials in design, Evolution of engineering materials and materials in products, Engineering materials and their properties, Design process, types and tools of design, materials data for design, Analyzation of design product function, design objective, constraints and free variables, steps of material selection in design process.

MATERIALS SELECTION:

Ashby method, material property charts, Materials selection strategy and procedure, material indices, materials selection procedure, the structural index, single and multiple constraints in material selection, conflicting objectives, Shape factors, limits to shape efficiency, exploring material-shape combinations, Materials indices that include shape factors, Hybrid materials designing, composites, Sandwich structures, Cellular structures, Segmented structures.

PROCESSING SELECTION:

Processes classification and attributes, Processes selection steps, Material-processes-shape relations, Processes selection screening and ranking, Materials and environments: Materials life-cycle, Energy-consuming characteristic of materials, Eco-attributes of materials, Eco-selection of materials.

MATERIALS FOR INDUSTRIAL DESIGN:

The requirements pyramid, Product character and personality, Design considerations in the use of materials are: quality control; selecting materials to optimize multiple properties; materials failure; long-term materials properties; materials behavior under extreme conditions; corrosion; discussion of design and materials selection strategy; processing and process selection strategy; process economics; life-cycle thinking and eco-design; special topics.

Text Books:

1. M.F. Ashby, Materials Selection in Mechanical Design, Butterworth Heinemann, 2005.
2. M.F. Ashby, Engineering Materials, Elsevier, 2005.
3. ASM Metals Handbook, Vol.20-Materials Selection and Design, ASM International, 1997
4. P. L. Mangonon, The Principles of Materials Selection and Design, Prentice Hall, 1999

MM414	Ceramics, Polymers, and Composites	DEC	3-0-0	3 Credits

Pre-requisites: None

Course Outcomes: At the end of the course, student will be able to:

CO1	State the properties and applications of metals, ceramics, polymers, composites.
CO2	Describe the routes of processing of ceramics, polymers and composites
CO3	Apply the rule of mixtures to estimate the properties of composites
CO4	Explain the strengthening mechanisms in composites
CO5	Select suitable ceramics, polymer and composite materials for a particular application

Course Articulation Matrix:

PO/PSO CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	S	-	-	-	-	-	-	-	-	-	-	-	-	-	S	L
CO2	S	-	-	-	-	-	-	-	-	-	-	-	-	-	S	
CO3	S	-	-	-	-	-	-	-	-	-	-	-	-	-	S	L
CO4	S	-	-	-	-	-	-	-	-	-	-	-	-	-	S	L
CO5	S	-	M	-	-	-	-	-	-	-	-	-	-	-	S	

S: Strong correlation, M: Medium correlation, L: Low correlation

Syllabus:

CERAMICS:

Introduction to ceramics, general properties of ceramics and applications. crystal structure, bonding in ceramics, silicate structure and clay materials, defects in ceramics structures, classification of ceramics, oxides ceramics, non-oxide ceramics, production of ceramic powders through various techniques- Sol gel, co-precipitation, solvent vaporization, fabrication of ceramics, porous ceramics, glasses, glass ceramics, super plasticity in ceramics, bio ceramics, creep mechanism in ceramics, toughening mechanism in ceramics, applications of ceramics.

POLYMERS:

Classification of Polymers, Addition and Condensation Polymerization, Degree of Polymerization, Typical Thermoplastics, Structure-Property Relationships in Thermoplastics, Effect of Temperature on Thermoplastics, Mechanical Properties of Thermoplastics, Elastomers, Thermosetting Polymers, Adhesives, Polymer Processing and Recycling, Mechanical behavior of polymers, Deformation and Strengthening of Plastic Materials, Creep and Fracture of Polymeric Materials, High Performance and Specialty Polymers, Polymer additives, compounding. Fillers, plasticizers, lubricants, colorants, UV stabilizers, fire retardants and antioxidants

COMPOSITES:

Introduction to Composites, properties and applications. Rule of mixture calculations, classification of composites based on matrix materials: metal matrix-, ceramic matrix-, and polymer matrix-composites. Classification of composites based on reinforcements: particulate reinforced, fibre reinforced composites, various fibre materials- glass, carbon, boron etc, hybrid composites, Fabrication of composites- Hand layout method, Injection molding, compression molding, resin transfer, pultrution, etc., fracture behaviour of composites, Case studies.

Text Books:

1. Michel W. Barsoum, Fundamentals of Ceramics, CRC press, 2020
2. Y.M. Chiang, D. P. Birnie, and W. D. Kingery, Physical Ceramics, Wiley, 1997
3. K. K. Chawla, Composite Materials-Science and Engineering, Springer, 2012.
4. F.L. Matthews and R.D. Rawlings, Composite Materials: Engineering and Science, CRC Press, 1999.
5. Anil Kumar and R. K. Gupta, Fundamentals of Polymer Engineering, CRC press, 2018
6. Joel R. Fried, Polymer Science and Technology, Pearson, 2014

MM415	Energy and Nuclear Materials	DEC	3-0-0	3 Credits

Pre-requisites: MM201-Physical Metallurgy

Course Outcomes: At the end of the course, student will be able to:

CO1	Identify the challenges in energy sector and describe the need of energy efficient materials technology
CO2	Categorize materials for energy generation and storage
CO3	Classify nuclear reactor components and suitable materials
CO4	Explain processing of nuclear grade materials

Course Articulation Matrix:

CO \ PO/PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	S	-	-	-	-	-	L	-	-	-	-	-	-	-	M	-
CO2	S	-	-	-	-	-	L	-	-	-	-	-	-	-	M	-
CO3	S	-	-	-	-	-	-	-	-	-	-	-	-	-	M	-
CO4	S	-	M	M	-	L	-	-	-	-	-	-	-	-	M	-

S: Strong correlation, M: Medium correlation, L: Low correlation

Syllabus:

INTRODUCTION:

Energy supply and consumption, Challenges in energy technology, Linkage between energy and materials, Requirement of energy efficient materials

ENERGY MATERIALS:

Materials for energy generation/conversion: Solar cells-photovoltaic materials, Fuel cells-solid state ionic materials, Energy harvesting-piezoelectric, magnetoelectric, thermoelectric, electrocaloric and magnetocaloric materials.

Materials for energy storage: thermal energy storage-phase change materials, electromagnetic energy storage-dielectric capacitors, electrochemical energy storage-lithium-ion batteries, supercapacitors.

NUCLEAR MATERIALS:

Nuclear Reactor Components and materials: Classification of nuclear reactors, Reactors and their components, Materials for nuclear reactors viz., fuels, moderators, control rods, coolants, reflectors and structural materials; Radiation effects on materials

Processing of Nuclear reactor Materials: Production of Nuclear Grade Materials, general methods of nuclear minerals processing. Production metallurgy of nuclear grade uranium, thorium, beryllium and zirconium. Production of enriched uranium. Processing of spent fuel and extraction of plutonium, Fabrication of fuel and cladding materials.

Reading:

1. Kathy Lu, Materials in energy conversion, harvesting, and storage, Wiley, 2014
2. CC Sorrell, Sumao Sugihar, and Janusz Nowotny (eds.), Materials for energy conversion devices, Woodhead Publishing, 2005
3. R.A. Huggins, Energy Storage- Fundamentals, Materials and Applications, Springer, 2016
4. K.L. Murty, I. Charit, An introduction to Nuclear materials, Wiley, 2013
5. Wolfgang Hoffelner, Materials for Nuclear Plants, Springer, 2012

MM416	Energy and Nuclear Materials	DEC	3-0-0	3 Credits

Pre-requisites: None

Course Outcomes: At the end of the course, student will be able to:

CO1	Explain the principles of the materials for smart applications
CO2	Describe the principles and applications of electric and magnetic smart materials.
CO3	Discuss the principles and applications of shape memory, self-healing and self-organizing materials.
CO4	Analyse the working principles and applications of chromic, green and energy materials.

Course Articulation Matrix:

CO \ PO/PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	S	-	-	-	-	-	-	-	-	-	-	-	-	-	M	-
CO2	S	-	-	-	-	-	-	-	-	-	-	-	-	-	M	-
CO3	S	-	-	-	-	-	-	-	-	-	-	-	-	-	M	-
CO4	S	M	-	-	-	-	-	-	-	-	-	-	-	-	M	-

S: Strong correlation, M: Medium correlation, L: Low correlation

Syllabus:

OVERVIEW OF SMART MATERIALS:

Introduction and definition of Smart Materials, principles of smart materials, input – output decision ability, devices based on conductivity changes, devices based on changes in optical response, biological systems smart materials. Devices based on magnetization, artificial structures, surfaces, hetero structures, polycrystalline, amorphous, liquid crystalline materials.

PIEZOELECTRIC AND MAGNETOSTRICTIVE MATERIALS:

Principles of Piezoelectricty, Perovskyte Piezoceramic Materials, Single Crystals vs Polycrystalline Systems, Piezoelectric Polymers, Principles of Magnetostriction, Rare earth Magnetostrictive materials, Giant Magnetostriction and Magneto- resistance Effect, magnetorheological fluids, electrorheological materials and their applications.

ELECTRO-ACTIVE MATERIALS:

Electronic Materials, Electro-active Polymers, Ionic Polymer Matrix Composites (IPMC)

SHAPE MEMORY ALLOYS:

Shape Memory Effect, Shape Memory Alloys, Shape Memory Polymers,

Self-Sensing Piezoelectric Transducers, Energy Harvesting Materials, Self- healing materials. Micro-electro mechanical Smart Systems, Intelligent devices based on smart materials, self-organizing nano materials

Smart materials in drug delivery, thermo-chromic and photo-chromic applications and hybrid and composite systems, green materials and Energy materials.

Text Books:

1. B. Culshaw, Smart Structures and Materials, Artech House, 2000
2. P. Gauenzi, Smart Structures: Physical Behaviour, Mathematical Modelling and Applications, Wiley Publishers, 2009
3. W. G. Cady, Piezoelectricity, Dover Publication, 1964
4. M. Addington, Schodek, L. Daniel.: Smart materials and new technologies, Architectural Press, 2005
5. W.D Callister, Materials Science and Engineering an Introduction, Willey 1999
6. M. Schwartz, Encyclopedia of Smart Materials, Volumes 1-2 ,Willey, 2002
7. Smith, C.: Smart material systems, Ralph, SIAM, 2005
8. K Vijay, K.Varadan, J. Vinoy, S.Gopalakrisham, Smart Material Systems and MEMS: Design and Development Methodologies , Willey 2006

MM449	Project Work-Part A	PRC	0-0-8	4 Credits

Pre-requisites: None

Course Outcomes: At the end of the course, student will be able to:

CO1	Identify a research problem after thorough literature review in metallurgical and materials engineering.
CO2	Plan and conduct preliminary experiments
CO3	Analyze the results and prepare a technical report
CO4	Make an oral presentation and answer the queries

Course Articulation Matrix:

CO \ PO/PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	S	M	M	M	S	L	L	M	S	S	M	L	L	L	L	L
CO2	S	M	M	M	S	L	L	M	S	S	M	L	L	L	L	L
CO3	S	M	M	M	S	L	L	M	S	S	M	L	L	L	L	L
CO4	S	M	M	M	S	L	L	M	S	S	M	L	L	L	L	L

S: Strong correlation, M: Medium correlation, L: Low correlation

MM461	Electronic and magnetic Materials	DEC	3-0-0	3 Credits

Prerequisite: PH101-Engineering Physics

Course Outcomes: At the end of the course, student will be able to:

CO1	Discuss the basics of electronic and magnetic properties of materials
CO2	Describe about conductors, semiconductors, and dielectric materials
CO3	Describe the origin of magnetism and types of conventional and advanced magnetic materials
CO4	Discuss the applications of electronic and magnetic materials

Course Articulation Matrix:

PO/PSO CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	S	-	-	-	M	-	-	-	-	-	-	-	-	-	M	-
CO2	S	-	-	-	M	-	-	-	-	-	-	-	-	-	M	-
CO3	S	-	-	-	M	-	-	-	-	-	-	-	-	-	M	-
CO4	S	-	-	-	M	-	-	-	-	-	-	-	-	-	M	-

S: Strong correlation, M: Medium correlation, L: Low correlation

Syllabus:

FUNDAMENTALS:

Electrons as waves and particles, Wave-function, Electron as a plane-wave, Operators, Schrodinger Equation, Wave-vector (k), Energy of free-electron as a function of wave-vector k (E vs k diagram, a parabola), k-space, Density of states, Fermi-sphere, -energy, -surface, -temperature, and –velocity, Electrons in a solid following Fermi-Dirac distribution, Electrons in a periodic-potential, Bloch Theorem, Kronig-Penny model, Origin of energy bands and band-gap, Free electron band diagram, Extended-, Periodic and reduced-zone representation for - k diagram, Allowed number of states in a band.

CONDUCTORS:

Conductivity and resistivity of metals and alloys and their temperature dependence, Applications of metals and alloys as conductors and resistors.

SEMICONDUCTORS:

Band diagrams, Classification of semiconductors (Intrinsic & Extrinsic), Doping, Carrier concentration with temperature, Direct and indirect band gaps, Band-gap measurements, Fermi level, Carrier concentration and mobility, Hall-effect. Temperature dependence of conductivity and resistivity.

DIELECTRIC MATERIALS:

Fundamental definitions in dielectrics, properties and different types of insulating materials, different types of polarization, frequency and temperature dependence of polarization, field vectors and their relation, Dielectric loss-Clausius-Mossotti Equation, Ferro-electricity and Piezo-electricity, optical properties of dielectrics.

MAGNETIC MATERIALS:

Origin of magnetism, orbital & spin, Permanent magnetic moments of atoms, Types of magnetic materials (Diamagnetic, Ferromagnetic, Ferrimagnetic and Anti-ferromagnetic),Weiss theory of ferromagnetism, Magnetic hysteresis, Domains, Susceptibility, Exchange energy, Bethe-Slater curve, Soft and hard magnetic materials, Permanent magnets - properties and preparation (SmCo & NdFeB),Ferrites-classification and crystal structure, Nanocrystalline soft magnetic materials, Melt-quenching method for soft magnetic ribbons, Super-paramagnetism, Single domain particle, Magnetic storage applications, Perpendicular magnetic recording media, Magnetic hyperthermia.

Text Books:

1. R. E. HuDMMEl, Electronic Properties of Materials, Springer, 2011
2. S.O. Kasap, Principles of Electronic Materials and Devices, McGraw Hill, 2018
3. David Jiles, Introduction to Electronic Properties of Materials, Taylor & Francis, 2001.
4. B. D. Cullity, C.D. Graham, Introduction to Magnetic Materials, Wiley, 2009
5. David Jiles, Introduction to Magnetism & Magnetic materials, Chapman & Hall, 1998.

MM462	Thin Films and Coatings	DEC	3-0-0	3 Credits

Prerequisite: PH101-Engineering Physics, CY101-Engineering Chemistry

Course Outcomes: At the end of the course, student will be able to:

CO1	Understand basic principles of different thin film deposition techniques
CO2	Describe methodology of vaccum and solution processing of films/coatings
CO3	Discuss physical and microstructural properties of thin films/coatings
CO4	Explain the applications of thin films and coatings

Course Articulation Matrix:

CO \ PO/PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	S	-	-	-	M	-	-	-	-	-	-	-	-	-	M	-
CO2	S	-	-	-	M	-	-	-	-	-	-	-	-	-	M	-
CO3	S	-	-	-	M	-	-	-	-	-	-	-	-	-	M	-
CO4	S	-	-	-	M	-	-	-	-	-	-	-	-	-	M	-

S: Strong correlation, M: Medium correlation, L: Low correlation

Syllabus:

THIN FILMS:

Vacuum systems: Need for vacuum, ways to achieve vacuum, determination of vacuum, dry and vapour pumps, pressure measurement gauges, conductance and other system design considerations.

Thin film deposition techniques:

Physical and chemical vapour deposition techniques including molecular beam epitaxy, laser ablation, magnetron sputtering, ion beam sputter deposition, reactive ion plating, Conventional CVD, Plasma Enhance CVD (PECVD) and Atomic layer deposition (ALD) techniques; Thermodynamic and kinetic considerations of deposition of thin films by both CVD and PVD; preparation of substrate-Role of substrate- substrate selection, nucleation and thin film growth

Characterization of thin films:

Residual stress and thickness measurements, electrical, optical, chemical and structural property determination.

Applications of thin films: sensors, optoelectronics, transistors, solar cells, etc.

Coatings:

Hard and decorative coatings; Processing techniques – dry and wet deposition techniques including electro-deposition, spin coating, sol-gel, Spray drying, Doctor blade technique, inkjet printing, etc; Physical, mechanical and protective properties - hardness, corrosion resistance, biocompatibility and high temperature stability; Applications-thermal barrier coatings, wear and corrosion resistant coatings, etc.

Text Books:

1. Milton Ohring, Materials Science of Thin Films, 2nd Edition, Academic Press, 2001
2. K. L. Chopra & L. K. Malhotra, Thin film Technology and Application, McGraw Hill, 1985
3. D. L. Smith, Thin Film deposition principle and Practice, McGraw Hill, 1995.
4. N. B. Dahotre & T.S. Sudarshan, Intermetallic and Ceramics Coatings, Mercel Dekker, 1999
5. Sam Zhang, Nanostructured Thin Films and Coating, CRC Press, 2010

MM463	Introduction to Nano Science and Technology	DEC	3-0-0	3 Credits

Pre-requisites: Materials Characterization
Course Outcomes: At the end of the course, student will be able to:

CO1	Identify the need for nano materials.
CO2	Appreciate the bottom up and top down approaches of nano material synthesis.
CO3	Describe the size effect on optical, electrical, mechanical, magnetic and thermal properties.
CO4	Review the applications of nano materials and nano devices

Course Articulation Matrix:

CO \ PO/PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	S	-	-	-	-	-	-	-	-	-	-	-	-	-	M	-
CO2	S	-	-	-	-	-	-	-	-	-	-	-	-	-	M	-
CO3	S	-	-	-	-	-	-	-	-	-	-	-	-	M		-
CO4	S	-	-	-	-	-	-	-	-	-	-	-	-	-	M	-

S: Strong correlation, M: Medium correlation, L: Low correlation

Syllabus:

INTRODUCTION:

History and Scope of nanomaterials, Classification of Nanostructured Materials, Size effects-Microstructure and Defects in Nanocrystalline Materials, Effect of Nano-dimensions on Materials Behaviour, Unique Properties of Nanomaterials, Applications of Nanomaterials

PROCESSING OF NANOMATERIALS:

Physical and chemical methods for fabrication of powders, bulk, films and other nanostructures, Bottom-Up approaches, Top-Down approaches

CHARACTERIZATION AND PROPERTIES OF NANOMATERIALS:

Structural Characterization-X-ray Diffraction (XRD), Small Angle X-ray Scattering (SAXS), Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM), Atomic Force Microscopy (AFM), Scanning Tunnelling Microscope (STM); Chemical Characterization-Optical spectroscopy, Electron spectroscopy, Ionic spectrometry; Physical properties of nanomaterials-melting points, mechanical properties, optical properties, quantum size effects.

NANOMATERIALS OF INTEREST:

Quantum dots, Carbon nanotubes, GaN Nanowires, Nanocrystalline ZnO, Nanocrystalline TiO_2

Text Books:

1. B. S. Murty et al., Textbook of Nanoscience and Nanotechnology, Universities Press, 2013
2. T. Pradeep et al., Textbook of Nanoscience and Nanotechnology, Tata McGrawHill, 2012
3. R.W. Kelsall, I.W. Hamley, and M. Geoghegan, Nanoscale Science & Technology, Wiley, 2005
4. G. Cao, Nanostructures and Nanomaterials, Imperial College Press, 2004

MM490	Materials Testing & Analysis	OPC	3-0-0	3 Credits

Pre-requisites: PH101-Engineering Physics, CY101-Engineering chemistry
Course Outcomes: At the end of the course, student will be able to:

CO1	Describe important physical properties of materials
CO2	Discuss procedures that can be used to identify or measure mechanical properties.
CO3	Analyze the microstructure and understand structure-property correlations
CO4	Select suitable material for a given purpose applying knowledge of material testing and structure of metallic materials

Course Articulation Matrix:

CO \ PO/PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	S	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-
CO2	S	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-
CO3	S	-	-	-	-	-	-	-	-	-	-	-	-	-	M	-
CO4	-	-	S	S	-	-	-	-	-	M	-	S	-	M	L	-

S: Strong correlation, M: Medium correlation, L: Low correlation

Syllabus:

INTRODUCTION:

Structures & Properties of engineering materials. Comparison of physical, thermal, and mechanical properties of metallic, ceramic, and polymeric materials, and composites. Scientific rationale for mechanical properties; cohesion between atoms, interatomic bonds, different levels of structures: atomic, crystal, micro, and macro and mega structures.

MECHANICAL TESTING:

Tension, Compression, Hardness, Torsion, Impact, Fatigue, and Creep

STRUCTURAL CHARACTERIZATION & ANALYSIS:

X-ray diffraction, optical microscopy & electron microscopy.

Text Books:

1. C. Suryanarayana, Experimental Techniques in Materials & Mechanics, CRC Press, 2011
2. D.Brandon, W. D. Kaplan, Microstructural Characterization of Materials, Wiley, 2008
3. P.R. Khangaonkar, Introduction to Material Characterization, Penram publishing, 2010

MM499	Project Work-Part B	PRC	0-0-12	6 Credits

Pre-requisites: MM449-Project Work Part A

Course Outcomes: At the end of the course, student will be able to:

CO1	Conduct and complete the experiments
CO2	Analyze the results and prepare a technical report
CO3	Make an oral presentation and answer the queries

Course Articulation Matrix:

CO \ PO/PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	S	M	M	M	S	L	L	M	S	S	M	L	L	L	L	L
CO2	S	M	M	M	S	L	L	M	S	S	M	L	L	L	L	L
CO3	S	M	M	M	S	L	L	M	S	S	M	L	L	L	L	L

S: Strong correlation, M: Medium correlation, L: Low correlation

Mandatory Online Course (Self Study)

Student is required to complete at least two courses offered by the following agencies. The student is required to take prior approval from the Department, before registering for any course. The student can register for such a course in 5th Semester and 7th semester. Unless the student submits a pass certificate, he/she shall not be eligible for the award of degree.

SWAYAM: www.swayam.gov.in

NPTEL: www.onlinecourse.nptel.ac.in

Coursera: www.coursera.org

edX Courses: www.edx.org

MIT Open Course ware: www.ocw.mit.edu

SAChE: Safety and Chemical Engineering Education Certification Program – https://www.aiche.org/ccps/education/safety-and-chemical-engineering-education-sache-certificate-program