NATIONAL INSTITUTE OF TECHNOLOGY ANDHRA PRADESH

SYLLABI
FOR B.TECH. PROGRAM

From 2017-18 Batch onwards

DEPARTMENT OF METALLURGICAL AND MATERIALS ENGINEERING

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

I - Year

Physics Cycle								
S. No.	**Course Code**	**Course Title**	**L**	**T**	**P**	**Credits**	**Cat. Code**
1	MA101	Mathematics – I	3	0	0	03	BSC
2	HS101	English for Technical Communication	2	0	2	03	HSC
3	PH101	Physics	3	0	0	03	BSC
4	EC101	Basic Electronic Engineering	3	0	0	03	ESC
5	CE102	Environmental Science and Engineering	2	0	0	02	ESC
6	BT101	Engineering biology	2	0	0	02	ESC
7	CS101	Problem Solving & Comp Programming	3	0	0	03	ESC
8	CS102	Problem Solving & Comp Programming Lab	0	1	2	02	ESC
9	PH102	Physics Laboratory	0	1	2	02	BSC
10	EA101	EAA: Games and Sports	0	0	3	00	MDC
		TOTAL	**18**	**2**	**9**	**23**	

Chemistry Cycle							
S.No	**Course Code**	**Course Title**	**L**	**T**	**P**	**Credits**	**Cat. Code**
1	MA151	Mathematics – II	3	0	0	03	BSC
2	ME102	Engineering Graphics	1	1	4	04	ESC
3	CY101	Chemistry	3	0	0	03	BSC
4	EE101	Basic Electrical Engineering	3	0	0	03	ESC
5	ME101	Basic Mechanical Engineering	3	0	0	03	ESC
6	CE101	Engineering Mechanics	3	0	0	03	ESC
7	ME103	Workshop Practice	0	1	2	02	ESC
8	CY102	Chemistry Laboratory	0	1	2	02	BSC
9	EA151	EAA: Games and Sports	0	0	3	00	MDC

		TOTAL	**16**	**3**	**11**	**23**	

B. Tech. II - Year I – Semester

S.No.	Course Code	Course Title	L	T	P	Credits	Cat. Cod
1	MA201	Mathematics- III	3	0	0	3	BSC
2	MM201	Physical Metallurgy	3	0	0	3	PCC
3	MM202	Unit Processes in Extractive Metallurgy	3	1	0	4	PCC
4	MM203	Metallurgical Thermodynamics	3	1	0	4	PCC
5	MM204	Transport Phenomena	3	0	0	3	PCC
6	MM205	Physical Metallurgy & Metallography Laboratory	0	1	2	2	PCC
7	MM206	Unit Processes in Extractive Metallurgy Laboratory	0	1	2	2	PCC
8	EE235	Basic Electrical Engineering Laboratory	0	1	2	2	ESC
		Total	**15**	**5**	**6**	**23**	

B. Tech. II - Year II – Semester

S.No.	Course Code	Course Title	L	T	P	Credits	Cat. Cod
1	MA251	Mathematics-IV	3	0	0	3	BSC
2	MM251	Phase Transformations and Heat Treatment	3	1	0	4	PCC
3	MM252	Solidification Processing	3	1	0	4	PCC
4	MM253	Iron Making Technology	3	0	0	3	PCC
5	MM254	Electronic and Magnetic Materials	3	0	0	3	PCC
6	MM255	Phase Transformations and Heat Treatment Laboratory	0	1	2	2	PCC
7	MM256	Solidification Processing laboratory	0	1	2	2	PCC
8	EC289	Basic Electronics Laboratory	0	1	2	2	ESC
		Total	**15**	**5**	**6**	**23**	

B. Tech. III - Year I – Semester

S.No.	Course Code	Course Title	L	T	P	Credits	Cat. Cod
1	SM335	Engineering Economics	3	0	0	3	HSC
2	MM301	Steel Making Technology	3	0	0	3	PCC
3	MM302	Mechanical Behavior of Materials	3	1	0	4	PCC
4	MM303	Powder Metallurgy	3	0	0	3	PCC
5		**Elective I**	3			3	DEC
6		**Elective II**	3	0	0	3	DEC
7	MM304	Mechanical Behavior of Materials Laboratory	0	1	2	2	PCC
8	MM305	Powder Metallurgy Laboratory	0	1	2	2	PCC
9	EP349	EPICS	0	0	0	2*	
		Total	**18**	**3**	**4**	**23**	

B. Tech. III - Year II – Semester

S.No.	Course Code	Course Title	L	T	P	Credits	Cat. Cod
1	MM351	Corrosion Engineering	3	1	0	4	PCC
2	MM352	Computational Materials Engineering	3	0	0	3	PCC
3	MM353	Materials Characterization	3	1	0	4	PCC
4		**Elective III**	3	0	0	3	DEC
5		**Open Elective I**	3	0	0	3	DEC
6	MM354	Corrosion Engineering Laboratory	0	1	2	2	PCC
7	MM355	Computational Materials Engineering laboratory	0	1	2	2	PCC
8	MM356	Materials Characterization Laboratory	0	1	2	2	PCC
9	EP399	EPICS	0	0	0	2*	OPC
		Total	**15**	**5**	**6**	**23**	

*Credits are not considered for computation of SGPA and CGPA in both Third year I and II Sem.

B. Tech. IV- Year I – Semester

S.No.	Course Code	Course Title	L	T	P	Credits	Cat. Cod
1	MM401	Metal Joining	3	0	0	3	PCC
2	MM402	Metal forming	3	1	0	4	PCC
3	MM403	Non Ferrous Extractive Metallurgy	3	1	0	4	PCC
4		**Elective IV**	3	0	0	3	DEC
5		**Open Elective II**	3	0	0	3	OPC
6	MM404	Metal Processing Laboratory	0	1	2	2	PCC
7	MM449	Project Work-Part A	0	0	4	2	PRC
8	MM491	Seminar	0	0	2	1	PCC
		Total	**15**	**3**	**8**	**22**	

B. Tech. IV- Year II – Semester

S.No.	Course Code	Course Title	L T P C Credits	T	P	Credits	Cat. Cod
1	SM452	Industrial Methods and Management	3	0	0	3	HSC
2	MM451	Ceramics and Composites Technology	3	0	0	3	PCC
3		**Elective V**	3	0	0	3	DEC
4		**Elective VI**	3	0	0	3	DEC
5		**Elective VII**	3	0	0	3	DEC
6	MM499	Project Work – Part B	0	0	8	4	PRC
		Total	**15**	**0**	**8**	**19**	

List of Departmental Electives

III Year I Semester

Elective I

MM311-Finite Element Methods
MM312-Fuels and Refractories
MM313-Mineral Processing

Elective II

MM314-Polymer Technology
MM315-Theory of Metallurgical Processes
MM316-Functional and Bio Materials

III Year II Semester

Elective III

MM361-Introduction to Nano science and Technology
MM362-Additive Manufacturing
MM363-Advanced Iron and Steel making Technology
MM390-Fundamentals of Materials Processing Technology (OPEN ELECTIVE - I)

IV Year I Semester

Elective IV

MM411-Physical Metallurgy of Non-ferrous Metals and Alloys
MM412-X-ray Diffraction
MM413-Nuclear Materials
MM414-Refractory and Rare Metal Extraction
MM440-Metallurgy for Non Metallurgists (OPEN ELECTIVE - II)

IV Year II Semester

Elective V

MM461-Surface Engineering
MM462-Energy Materials
MM463-Pollution and its Control in Metallurgical Industries
MM464-Metallurgical waste recycling

Elective VI

MM465-Non Destructive Testing
MM466-Metallurgical failure analysis
MM467-Materials selection and design
MM468-High Temperature Materials

Elective VII

MM469-Advanced Material Characterization Techniques
MM470-Special Steels and Alloys
MM471-Smart Materials

Mandatory Audit Course (Self Study)

Student is required to complete at least one course 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 either in 6^{th} Semester or 7^{th} semester. Unless the student submits a pass certificate, he/she shall not be eligible for the award of degree.

SAChE: Safety and Chemical Engineering Education Certification Program – www.aiche.org

SWAYAM:

www.swayam.gov.in NPTEL:

www.onlinecourse.nptel.ac.in

Course Era:

www.coursera.org

Free Online Courses: www.edx.org

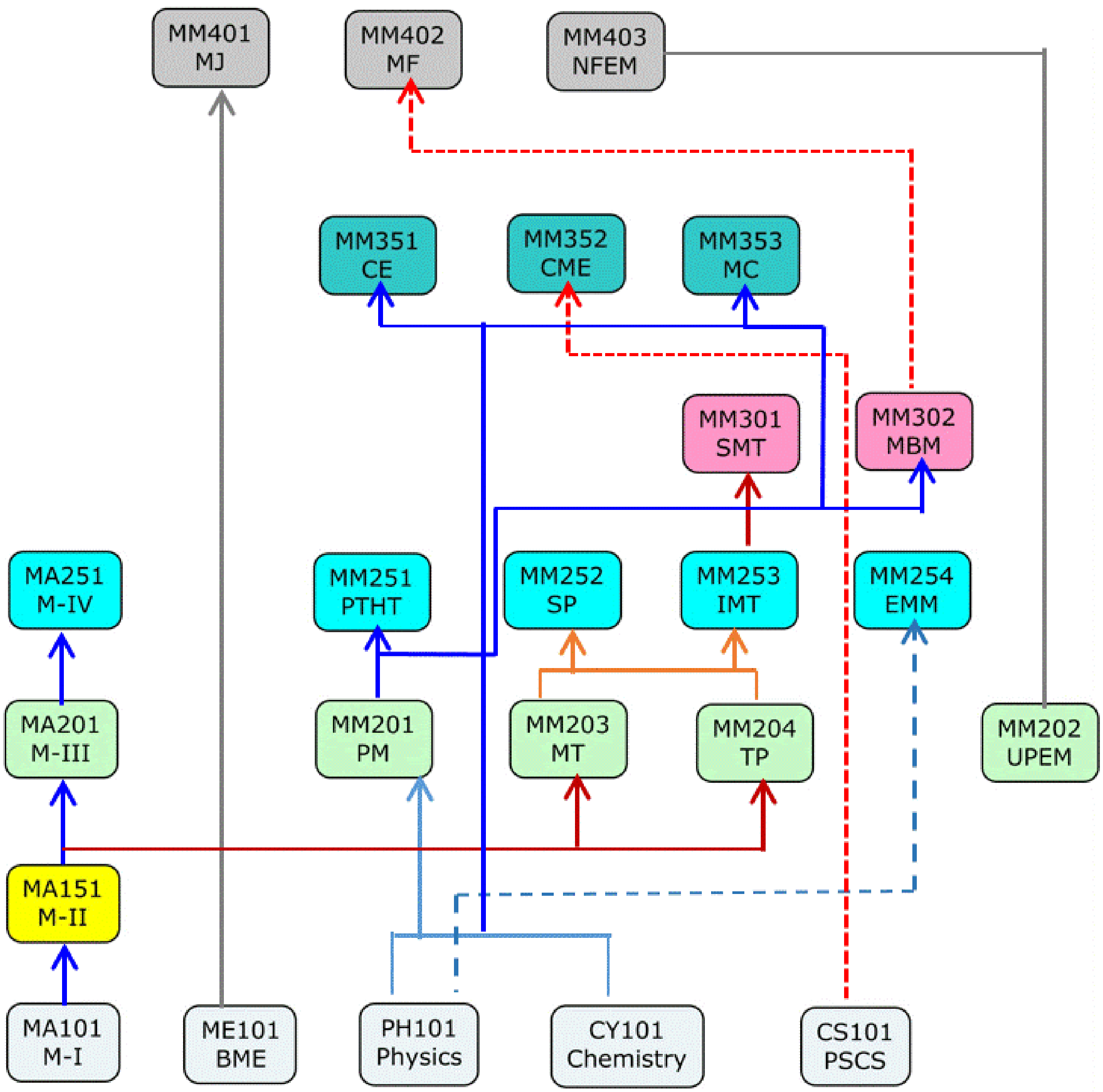
MIT Open Course ware: www.ocw.mit.edu

Points to be noted:

1. Definition of Pre-requisite: The student should have studied that subject which is mentioned as Pre-requisite.
2. Course with same name but with different code number indicates that the subject pertains to different departments and also the syllabus is different.
3. EPICS (Engineering Project in Community Service) Project is offered in two parts as Part- A in III Year II Semester and Part-B in IV Year I semester, with Two credits each. The credits earned are not counted for Computation of SGPA and CGPA. The course is not mandatory. It is Optional. Interested students can take it.
4. In first year syllabus, Engineering Biology is included in Physics cycle and Basic Mechanical Engineering is included in Chemistry cycle. This is with effect from 2018-2019 onwards

B.TECH IN METALLURGICAL AND MATERIALS ENGINEERING

PRE-REQUISITE CHART



Mathematics - I

[For I B.Tech. I Semester - all sections]

MA 101	Mathematics - I	BSC	3-0-0	3 Credits

Pre-requisites: None

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

CO 1	solve the consistent system of linear equations
CO 2	apply orthogonal and congruent transformations to a quadratic form
CO 3	determine the power series expansion of a given function
CO 4	find the maxima and minima of multivariable functions
CO 5	solve arbitrary order linear differential equations with constant coefficients
CO 6	apply the concepts in solving physical problems arising in engineering

Mapping of course outcomes with program outcomes

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	3	2	2	-	-	-	-	-	-	-	-	-	-	-	-	-
CO2	3	2	2	-	-	-	-	-	-	-	-	-	-	-	-	-
CO3	3	2	2	-	-	-	-	-	-	-	-	-	-	-	-	-
CO4	3	2	2	-	-	-	-	-	-	-	-	-	-	-	-	-
CO5	3	2	2	-	-	-	-	-	-	-	-	-	-	-	-	-
CO6	-	-	3	-	-	-	-	-	-	-	-	2	1	-	-	-

Detailed 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 and congruent transformation; Properties of complex matrices - Hermitian, skew-Hermitian and Unitary matrices.

Differential Calculus: Taylor's theorem with remainders; Taylor's and Maclaurin's expansions; Asymptotes; Curvature; Curve tracing; Functions of several variables - 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.

Ordinary Differential Equations: Geometric interpretation of solutions of first order ODE $y' = f(x, y)$; Exact differential equations; integrating factors; orthogonal trajectories; 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.

Readings:

1. R. K. Jain and S. R. K. Iyengar, *"Advanced Engineering Mathematics"*, Fifth Edition, Narosa Publishing House, 2016
2. Erwin Kreyszig, *"Advanced Engineering Mathematics"*, Eighth Edition, John Wiley and Sons, 2015
3. B. S. Grewal, *"Higher Engineering Mathematics"*, Khanna Publications, 2015

ME102	ENGINEERING GRAPHICS	ESC	2 - 0 - 4	4 Credits

Pre-requisites: None.

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

CO1	Recall BIS standards and conventions while drawing Lines, printing Letters and showing Dimensions.
CO2	Classify the systems of projection with respect to the observer, object and the reference planes.
CO3	Construct orthographic views of an object when its position with respect to the reference planes is defined.
CO4	Analyse the internal details of an object through sectional views.
CO5	Relate 2D orthographic views to develop 3D Isometric View.
CO6	Construct 2D (orthographic) and 3D (isometric) views in CAD environment.

Mapping of course outcomes with program outcomes:

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO2	3	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
CO3	3	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
CO4	3	2	-	2	-	-	-	-	-	-	-	-	1	-	-	-
CO5	3	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO6	3	2	-	-	2	-	-	-	-	-	-	-	1	-	-	-

DETAILED SYLLABUS:

Introduction: Overview of the course, Lines Lettering and Dimensioning: Types of lines, Lettering, Dimensioning, Geometrical Constructions, Polygons, Scales

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

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.

Section 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.

Auto-CAD Practice: Introduction to Auto-CAD, DRAW tools, MODIFY tools, TEXT, DIMENSION, PROPERTIES

Text Book:

N.D. Bhat and V.M. Panchal, Engineering Graphics, Charotar Publishers, 2013

Reference Book:

Sham Tickoo, “AutoCAD 2017 for Engineers & Designers", 23ed, Dreamtech Press, 2016

PH101	PHYSICS	PCC	3-0-0	3 credits

Pre-requisites: None

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

CO 1	Solve engineering problems using the concepts of wave and particle nature of radiant energy.
CO 2	Understand the use of lasers as light sources for low and high energy applications.
CO 3	Understand the nature and characteristics of new Materials for engineering applications.
CO 4	Apply the concepts of light propagation in optical fibers, light wave communication systems, holography and for sensing physical parameters.
CO 5	Apply the knowledge of Solar PV cells for choice of materials in efficient alternate energy generation.

Mapping of course outcomes with program outcomes

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	3	2	-	-	-	-	-	-	-	-	-	-	-	-	-	1
CO2	3	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
CO3	3	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
CO4	3		2	-	-	-	-	-	-	-	-	-	-	-	-	-
CO5	3	-	-	-	-	-	3	-	-	-	-	2	-	-	2	-

Detailed Syllabus:

1. Quantum Mechanics:

Concepts and Experiments that led to the discovery of Quantum Nature. Heisenberg uncertainty principle; Schrodinger time independent and time dependent wave equations, The free particle problem - Particle in an infinite and finite potential well, Quantum mechanical tunneling. MB, BE and FD distributions.

2. Wave and Quantum Optics:

Interference and Diffraction: Concept of interference and working of Fabry-perot Interferometer and its application as wavelength filter. Multiple beam diffraction and Working of diffraction Gratings, Application of Grating as wavelength splitter. **Polarization Devices:** Principles, Working and applications of Wave Plates, Half Shade Polari meter, Polari scope, Isolators and Liquid Crystal Displays. **Lasers:** Basic theory of Laser, Concept of population inversion and Construction and working of He-Ne, Nd-YAG, CO_2 Lasers, LED, White light LED, Semiconductor Laser, Holography and NDT. **Optical Fibers**: Structure, Types, Features, Light guiding mechanism and applications in Communications and Sensing. **Solar Cells:** Solar spectrum, photovoltaic effect, materials, structure and working principle, I-V characteristics, power conversion efficiency, quantum efficiency, emerging PV technologies, applications.

3. Magnetic and Dielectric Materials:

Magnetic Materials and Superconductors: Introduction - Weiss Theory of Ferromagnetism – Properties – Domains – Curie Transition - Hard and soft magnetic materials – Spinel Ferrites – Structure – Classification – Applications - Meissner effect - Type-I and Type-II Superconductors – Applications.

Dielectric Materials:

Introduction to Dielectrics, Dielectric constant – Polarizability - Properties and types of insulating materials **-** Polarization mechanisms in dielectrics (Qualitative) – Frequency and temperature dependence of polarization –Dielectric loss Clausius-Mossotti Equation (Qualitative) – dielectric Breakdown - Applications.

4. Functional and Nano Materials:

Functional Materials: Fiber reinforced plastics, fiber reinforced metals, surface acoustic wave materials, Bio-materials, high temperature materials and smart materials - Properties and applications.

Nanomaterials: Introduction, classification, properties, different methods of preparation and applications.

Reading:

1. Halliday, Resnic and Walker, Fundamentals of Physics, 9th Edition, John Wiley, 2011.
2. Beiser A, Concepts of Modern Physics, 5th Ed., McGraw Hill International, 2003.
3. Ajoy Ghatak, Optics, 5th Ed., Tata McGraw Hill, 2012.
4. S.O.Pillai, Solid State Physics, New Age Publishers, 2015.

CY101	**CHEMISTRY**	BSC	3 – 0 – 0	3 Credits

Pre-requisites: None.

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

CO1	The basic knowledge of the organic reaction mechanism and intermediates.
CO2	The basic knowledge of methods of chemical structure analysis and the instrumentation involved.
CO3	The potential energy aspects of fuel cells, rechargeable batteries and new materials for their fabrication.
CO4	About optical fibres, liquid crystals, LCD, LED, OLED, conducting polymers and their applications.
CO5	The quantum and thermodynamic aspects of various types of bonding, coordination complexes and chemical and enzymatic reactions.
CO6	The synthetic methodologies, importance and applications of nanomaterials in different fields.

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	**2**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO2	**2**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO3	**2**	-	-	-	-	-	-	-	-	-	-	-	-	-	**2**	-
CO4	**2**	-	-	-	-	-	-	-	-	-	-	-	-	-	**1**	-
CO5	**2**	-	-	-	-	-	-	-	-	-	-	-	-	-	**1**	-
CO6	**2**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

<u>Detailed Syllabus:</u>

1: Quantum Chemistry and Chemical Bonding:

Emergence of Quantum Theory; Postulates of Quantum Mechanics, Operators and Observables, Schrodinger Equation, Particle in a One-Dimensional Box and Colour of Conjugate Molecules, Hetero-diatomic Molecule as Harmonic Oscillator and Rigid Rotor, Hydrogen Atom, LCAO-MO Theory (MO Diagram of CO and NO Molecules)

2: Chemical Thermodynamics:

Enthalpy and Free Energy Changes in Chemical Reactions; Relevance of $C_p$and C_v in Gas Phase Reactions, Chemical Potential; Heat Capacity of Solids, Absolute Entropy and Third Law of Thermodynamics

3: Electrochemistry:

Electrodes and Electrochemical Cells; Potentiometric and Amperometric Sensors; Li-Ion and Ni-Cd Rechargeable Batteries; Fuel Cells (Methanol-Oxygen); Electrochemical Theory of Corrosion; Factors Affecting Rate of Corrosion; Sacrificial Anodic and Impressed Current Cathodic Protection.

4: Coordination Chemistry and Organometallics:

Shapes of Inorganic Compounds; Crystal Field and Molecular Orbital Theories; MO-Diagram for an Octahedral Complex; Metal Ions in Biology; Organometallic Chemistry (Metal Carbonyls).

5: Basics of Organic Chemistry:

Classification of Organic reaction and their mechanisms. Reaction intermediates: formation, structure and properties.Named Reactions: Skraup's synthesis, Diels- Alder reaction, Click Reactions.

6: Engineering Materials and Application:

Inorganic and Organic polymers - Zeolites, resins, polymeric membranes, conducting polymers, Applications - optical fibres, OLED, water purification.

7: Instrumental Methods of Chemical Analysis:

Gas- and Liquid-Chromatographic Separation of Components of Mixtures; UV-Visible, FTIR, NMR and Mass Spectral Methods of Analysis of Structures of Organic Compounds, Radiometry.

Reading:

1. A Textbook of Engineering Chemistry, Shashi Chawla, Dhanpat Rai, 2017.
2. Elements of Physical Chemistry, P. Atkins and Julio de Paula, 7th Edition, Oxford UP, 2017.
3. Engineering Chemistry, Shikha Agarwal, Cambridge UP, 2015.
4. Concise Inorganic Chemistry, J.D. Lee, 5th Edition, OUP, 2008.
5. Organic Chemistry, Clayden, Greaves, Warren and Wothers, Oxford University, 2014.
6. Organic Chemistry, Paula Bruce, Pearson, 7th Edition, 2013.

EC101	Basic Electronic Engineering	ESC	3-0-0	3-credits

Pre-requisites: none

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

CO 1	Comprehend the characteristics of semiconductor devices, and operational amplifiers
CO 2	Understand the principles of working of amplifiers
CO 3	Understand and design of simple combinational and basics of sequential logic circuits
CO 4	Understand the principles of electronic measuring instruments and Transducers
CO 5	Understand the basic principles of electronic communication

Mapping of course outcomes with program outcomes:

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	**2**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO2	**2**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO3	**2**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO4	**2**	-	-	-	**1**	-	-	-	-	-	-	-	-	-	-	**2**
CO5	**2**	-	-	-	**1**	-	-	-	**1**	-	-	-	-	-	-	-

Detailed Syllabus:

Electronics Systems: Introduction to electronics, review of p-n junction operation, diode applications, Zener diode as regulator.

Transistor and applications: Introduction to transistors, BJT Characteristics, biasing and applications, simple RC coupled amplifier and frequency response. FET and MOSFET characteristics and applications.

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

Integrated Circuits: Operational amplifiers – characteristics and linear applications

Digital Circuits: Number systems and logic gates, Combinational Logic circuits, Flip-Flops, counters and shift registers, data converters, Analog to Digital and Digital to Analog converters (ADC/DAC's), Introduction to microprocessors and microcontrollers.

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

Electronics Instrumentation: Measurement, Sensors, principles of LVDT, strain gauge and thermocouples. Introduction to data acquisition system.

Principles of Communication: Need for Modulation, Definitions of various Modulation and Demodulation techniques, AM radio transmitter and receiver, brief understanding of FM and mobile communications.

Readings:

1. Bhargava N. N., D C Kulshreshtha and S C Gupta, Basic Electronics & Linear Circuits, 2^{nd} Edition, Tata McGraw Hill, 2013.
2. Malvino and Brown, "Digital Computer electronics" Mcgraw Hill, 3^{rd} Edition.
3. Keneddy and Davis, "Electronic Communication Systems" Mcgraw Hill, 4^{th} Edition.
4. Helfrick and Cooper, " Modern Electronic Instrumentation and Measurement Techniques" PHI, 2011
5. Salivahanan, N Suresh Kumar Electronic Devices and circuits, 3rd Edition, McGraw Hill publications.
6. Neil Storey, Electronics A Systems Approach, 4^{th} Edition, Pearson Education Publishing Company Pvt Ltd.

EE101	BASIC ELECTRICAL ENGINEERING	ESC	3 – 0 – 0	3 Credits

Pre-requisites: None.

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

CO1	Analyze and solve electric and magnetic circuits
CO2	Identify the type of electrical machines for a given application
CO3	Recognize the ratings of different electrical apparatus
CO4	Identify meters for measuring electrical quantities and requirements of illumination

Mapping of course outcomes with program outcomes:

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	2	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO2	2	1	-	-	-	-	-	-	-	-	-	-	1	-	-	-
CO3	2	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO4	2	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Detailed Syllabus:

DC Circuits: Kirchoff's Voltage and Current Laws, Superposition Theorem, Star-Delta Transformations

AC Circuits: Complex representation of Impedance, Phasor diagrams, Power & Power Factor, Solution of 1-ϕ Series & Parallel Circuits, Solution of 3-ϕ circuits and Measurement of Power in 3-ϕ circuits

Magnetic Circuits: Fundamentals and solution of Magnetic Circuits, Concepts of Self and Mutual Inductances, Coefficient of Coupling

Single Phase Transformers: Principle of Operation of a Single Phase Transformer, EMF Equation, Phasor Diagram, Equivalent Circuit of a 1-ϕ Transformer, Determination of Equivalent circuit parameters, calculation of Regulation & Efficiency of a Transformer

DC Machines: Principle of Operation, Classification, EMF and Torque Equations, Characteristics of Generators and Motors, Speed Control Methods and Applications

Three Phase Induction Motor: Principle of Rotating Magnetic Field, Principle of Operation of 3-ϕ Induction Motor, Torque – Speed Characteristics of 3-ϕ Induction Motor, Applications

Measuring Instruments: Moving Coil and Moving Iron Ammeters and Voltmeters

Illumination: Laws of illumination and luminance

Text Book/References:

1. Edward Hughes, Electrical & Electronic Technology – 12th Edition, Pearson, 2016.
2. Vincent Del Toro, Electrical Engineering Fundamentals – 2nd Edition, Pearson, 2015.
3. V N Mittle& Arvind Mittal, Basic Electrical Engineering – 2nd Edition TMH 2005.
4. E. Openshaw Taylor, Utilization of Electrical Energy – Orient Longman, 2010

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

Pre-requisites: None.

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

CO1	Identify environmental problems arising due to engineering and technological activities and the science behind those problems.
CO2	Estimate the population - economic growth, energy requirement and demand.
CO3	Analyse material balance for different environmental systems.
CO4	Realize the importance of ecosystem and biodiversity for maintaining ecological balance.
CO5	Identify the major pollutants and abatement devices for environmental management and sustainable development

Correlation between the Course Outcomes (CO) and the Program Outcomes (PO)

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	3	-	-	-	-	-	3	2	-	-	-	-	-	-	-	-
CO2	3	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-
CO3	3	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
CO4	3	-	-	-	-	-	3	3	-	-	-	-	-	-	-	-
CO5	3	-	-	-	-	-	3	3	-	-	-	-	-	-	-	-

Detailed Syllabus:

Unit 1: Introduction to Environmental Science:

Environment and society, major environmental issues: Ozone layer depletion, Acid rains, global climate change etc, sustainable development, Environmental impact assessment, environmental management

Unit 2: Natural Resources Utilization and its Impacts:

Energy, minerals, water and land resources, Resource consumption, population dynamics, urbanization.

Unit 3: Ecology and Biodiversity:

Energy flow in ecosystem, food chain, nutrient cycles, eutrofication, value of biodiversity, biodiversity at global, national and local levels, threats for biodiversity, conservation of biodiversity

Unit 4: Water Pollution:

Sources, types of pollutants and their effects, water quality issues, contaminant transport, self-purification capacity of streams and water bodies, water quality standards, principles of water and wastewater treatment.

Unit 5: Air Pollution:

Sources, classification and their effects, Air quality standards, dispersion of pollutants, control of air pollution, automobile pollution and its control.

Unit 6: Solid Waste Management:

Sources and characteristics of solid waste, effects, Collection and transfer system, disposal methods

Readings:

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. W P Cunningham, M A Cunningham, Principles of Environmental Science, Inquiry and Applications, Tata McGraw Hill Publishing Company Ltd, New Delhi.
4. M. Chandrasekhar, Environmental science, Hi Tech Publishers, 2009.

ME101	BASIC MECHANICAL ENGINEERING	ESC	3 - 0 - 0	3 Credits

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

CO1	Identify Materials for Engineering Applications
CO2	Describe the functions and operations of Conventional, NC, CNC and 3D Printing methods of manufacturing.
CO3	Select a power transmission system for a given application.
CO4	Understand the concepts of thermodynamics and functions of components of a power plant.
CO5	Understand basics of heat transfer, refrigeration, internal combustion engines and Automobile Engineering.

Mapping of course outcomes with program outcomes

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO2	3	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-
CO3	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO4	3	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
CO5	3	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-

DETAILED SYLLABUS:

Engineering Materials: Introduction to Engineering Materials, Classification and Properties

Manufacturing Processes: Castings – Patterns & Moulding, Hot Working and Cold Working, Metal Forming processes: Extrusion, Drawing, Rolling, Forging, Welding – Arc Welding & Gas Welding, Soldering, Brazing.

Machine Tools: Lathe – Types – Operations, Problems on Machining Time Calculations, Drilling M/c – Types – Operations, Milling M/c – Types – Operations – Up & Down Milling, Shaping M/c – Operations – Quick Return Mechanism, Planer M/c. – Operations – Shaper Vs Planer, Grinding M/c – Operations. 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: Energy Sources – Conventional/Renewable, Thermodynamics – System, State, Properties, Thermodynamic Equilibrium, Process & Cycle, Zeroth law of Thermodynamics, Work & Heat, First law – Cyclic process, Change of State, C_p, C_v, PMM1,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.

Thermal Power Plant: Layout of Thermal Power Plant & Four circuits – Rankine cycle, T-s & P-v diagrams, Boilers – Babcock & Wilcox, Cochran Boilers, Comparison of Fire Tube &Water Tube Boilers, Steam Turbines – Impulse Vs. Reaction, Compounding – Pressure & Velocity Compounding, Condensers – Jet Condenser and Surface Condenser; Cooling Towers.

I.C. Engines: 2-Stroke & 4-Stroke Engines, P-v Diagram; S.I. Engine, C.I. Engine, Differences

Refrigeration: Vapor Compression Refrigeration Cycle – Refrigerants, Desirable Properties of Refrigerants

Heat Transfer: Modes of Heat Transfer, Thermal Resistance Concept, Composite Walls & Cylinders, and Overall Heat Transfer Coefficient – problems

Automobile Engineering: Layout of an Automobile, Transmission, Clutch, Differential, Internal Expanding Shoe Brake

Readings:

1. M.L.Mathur, F.S.Mehta and R.P.Tiwari, R.S.Vaishwnar, “Elements of Mechanical Engineering”, Jain Brothers, New Delhi, 2008.
2. Praveen Kumar, “Basic Mechanical Engineering”, Pearson Education, India, 2013.
3. P.N. Gupta, M.P. Poonia, “Elements of Mechanical Engineering”, Standard Publishers, 2004.
4. C.P.Gupta, Rajendra Prakash, “Engineering Heat Transfer”,Nem Chand Brothers, New Delhi, 1994.
5. B.S.Raghuvanshi, “Workshop Technology, Vol. 1&2”, Dhanpath Rai & Sons, New Delhi, 1989.

CS101	**PROBLEM SOLVING AND COMPUTER PROGRAMMING**	**ESC**	**3 – 0 –0**	**3 Credits**

Pre-requisites: None.

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

CO1	Design algorithms for solving simple mathematical problems including computing, searching and sorting
CO2	Compare and contrast algorithms in terms of space and time complexity to solve simple mathematical problems
CO3	Explore the internals of computing systems to suitably develop efficient algorithms
CO4	Examine the suitability of data types and structures to solve specific problems
CO5	Apply control structures to develop modular programs to solve mathematical problems
CO6	Apply object oriented features in developing programs to solve real world problems

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	3	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
CO2	3	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
CO3	3	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-
CO4	3	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-
CO5	3	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-
CO6	3	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-

Detailed Syllabus:

Fundamentals of Computers, Historical perspective, Early computers, Components of a computers, Problems, Flowcharts, Memory, Variables, Values, Instructions, Programs.

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

Number systems and data representation, Basics of C++, Basic data types.

Numbers, Digit separation, Reverse order, Writing in words, Development of Elementary School Arithmetic Testing System, Problems on Date and factorials, Solutions using flow of control constructs, Conditional statements - If-else, Switch-case constructs, Loops - while, do-while, for.

Functions – Modular approach for solving real time problems, user defined functions, library functions, parameter passing - call by value, call by reference, return values, Recursion, Introduction to pointers.

Sorting and searching algorithms, large integer arithmetic, Single and Multi-Dimensional Arrays, passing arrays as parameters to functions

Magic square and matrix operations using Pointers and Dynamic Arrays, Multidimensional Dynamic Arrays

String processing, File operations.

Structures and Classes - Declaration, member variables, member functions, access modifiers, function overloading, Problems on Complex numbers, Date, Time, Large Numbers.

Reading:

1. Walter Savitch, Problem Solving with C++, Ninth Edition, Pearson, 2014.
2. Cay Horstmann, Timothy Budd, Big C++, Wiley, 2nd Edition, 2009.
3. R.G. Dromey, How to solve it by Computer, Pearson, 2008.

CE101	ENGINEERING MECHANICS	ESC	3 – 0 – 0	3 Credits

Pre-requisites: None.

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

CO1	Determine the resultant force and moment for a given system of forces
CO2	Analyze planar and spatial systems to determine the forces in members of trusses, frames and problems related to friction
CO3	Calculate the motion characteristics of a body subjected to a given force system
CO4	Determine the deformation of a shaft and understand the relationship between different material constants
CO5	Determine the centroid and second moment of area

Mapping of course outcomes with program outcomes

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO2	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO3	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO4	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO5	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Detailed syllabus:

Introduction - Specification of force vector, Formation of Force Vectors, Moment of Force – Cross product – Problems, Resultant of a general force system in space, Degrees of freedom - Equilibrium Equations, Kinematics – Kinetics – De' Alemberts principle, Degree of Constraints – Freebody diagrams.

Spatial Force systems - Concurrent force systems - Equilibrium equations – Problems, Problems (Vector approach) – Tension Coefficient method, Problems (Tension Coefficient method), Parallel force systems - problems, Center of Parallel force system – Problems.

Coplanar Force Systems - Introduction – Equilibrium equations – All systems, Problems on Coplanar Concurrent force system, Coplanar Parallel force system, Coplanar General force system – Point of action, Method of joints, Method of sections, Method of sections, Method of members, Friction – Coulombs laws of dry friction – Limiting friction, Problems on Wedge friction, Belt Friction-problems.

Mechanics of Deformable Bodies - Stress & Strain at a point- Normal and shear stresses, Axial deformations – Problems on prismatic shaft, tapered shaft and deformation due to self-weight, Deformation of Stepped shaft due to axial loading, Poisson's Ratio – Bulk Modulus - Problems, change in dimensions and volume.

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

Dynamics of Particles - Rectilinear Motion – Kinematics Problems, Kinetics – Problems, Work & Energy – Impulse Moment, Curvilinear Motion – Normal and tangential components

Readings:

1. J.L.Meriam and L.G. Kraige, Engineering Mechanics, 7th Edition, John Wiley &Sons, 2012.
2. Timoshenko and Young, Engineering Mechanics, 3rd Edition, McGraw Hill Publishers, 2006.
3. Gere and Timoshenko, Mechanics of Materials, 2nd Edition, CBS Publishers, 2011.

CY102	CHEMISTRY LABORATORY	BSC	0- 1- 2	2 Credits

Pre-requisites: None.

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

CO1	Select a suitable methodology and compare the strategies involved in the estimation of metal content, iodine content, active chlorine or hardness of water for various applications.
CO2	Apply a selective instrumental method in the place of tedious and complex titration processes for repeated and regulated analysis of acids, bases, redox compounds, etc.
CO3	Test and validate optical activity, corrosion inhibitor efficiency and absorption isotherm of selective compounds and processes.

Mapping of course outcomes with program outcomes

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	3	2	1	2	-	-	-	-	-	-	-	-	3	-	-	3
CO2	3	2	1	2	-	-	-	-	-	-	-	-	3	-	-	3
CO3	3	2	1	2	-	-	-	-	-	-	-	-	3	-	-	3

Detailed Syllabus:

Cycle-I

1. Standardization $KMnO_4$ solution: Understanding the redox process, electron transfer, importance of qualitative and quantitative analysis.
2. Estimation of Hematite: Understanding the importance on purity of an ore, % of metal content (for Fe).
3. Hardness of Water: Understanding of metal complexes, multi dentate ligands, importance of purity of ground water, (EDTA method; complexometry).
4. Analysis of bleaching powder for available chlorine: Understanding the importance and purity of potable water, back titration (Iodometry).
5. Preparation of nanomaterials: Understanding the importance of nanomaterial, their preparation and characterization.

Cycle II

1. pH metry: Concept of pH, Instrumentation, calibration, determination of the concentrations by instrumental methods
2. Conductometry: Concept of conductivity, importance of conductivity

3. Potentiometry: Determination of the redox potential of the reaction
4. Colorimetry: Importance of Beers and Lamberts law,
5. Photochemical experiment: Importance of visible light and its application for a redox process, importance of coloring agent
6. Preparation of bakelite / polypyrrole: Concepts of organic reactions and application for the organic material preparation.
7. Corrosion experiment: Concept of corrosion, importance of corrosion agents
8. Adsorption experiment: Understanding phenomena of adsorption and absorption
9. Analysis of a drug: Importance of the purity, concentrations of a drug molecule.

Reading:

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

CS102	PROBLEM SOLVING AND COMPUTER PROGRAMMING LAB	ESC	0 – 1 – 2	2 Credits

Pre-requisites: None.

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

CO1	Design and test programs to solve mathematical and scientific problems
CO2	Develop and test programs using control structures
CO3	Implement modular programs using functions
CO4	Develop programs using classes

Mapping of course outcomes with program outcomes

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	**3**	-	-	-	**2**	-	-	-	-	-	-	-	-	-	-	-
CO2	**3**	-	-	-	**2**	-	-	-	-	-	-	-	-	-	-	-
CO3	**3**	**2**	**2**	-	**2**	-	-	-	-	-	-	-	-	-	-	-
CO4	**3**	-	-	-	**2**	-	-	-	-	-	-	-	-	-	-	-

Detailed Syllabus:

Laboratory:

1. Programs on conditional control constructs.
2. Programs on loops (while, do-while, for).
3. Programs using user defined functions and library functions.
4. Programs on arrays, matrices (single and multi-dimensional arrays).
5. Programs using pointers (int pointers, char pointers).
6. Programs on structures.
7. Programs on classes and objects.

Reading:

1. Walter Savitch, Problem Solving with C++, Ninth Edition, Pearson, 2014.
2. Cay Horstmann, Timothy Budd, Big C++, Wiley, 2nd Edition, 2009.
3. R.G. Dromey, How to solve it by Computer, Pearson, 2008.

ME103	WORKSHOP PRACTICE	ESC	0 - 0 - 3	2 Credits

Pre-requisites: None.

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

CO1	Study and practice on machine tools and their operations
CO2	Practice on manufacturing of components using workshop trades including fitting, carpentry, foundry and welding
CO3	Identify and apply suitable tools for machining processes including turning, facing, thread cutting and tapping
CO4	Apply basic electrical engineering knowledge for house wiring practice

Mapping of course outcomes with program outcomes

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	3	-	-	-	3	-	-	-	-	-	-	-	2	-	-	-
CO2	3	-	-	-	3	-	-	-	-	-	-	-	2	-	-	-
CO3	3	-	-	-	3	-	-	-	-	-	-	-	2	-	-	-
CO4	3	-	-	-	3	-	-	-	-	-	-	-	2	-	-	-

DETAILED SYLLABUS:

Fitting Trade: 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.

Plumbing: Practice of Internal threading, external threading, pipe bending, and pipe fitting, Pipes with coupling for same diameter and with reducer for different diameters and Practice of T-fitting,Y-fitting, Gate valves fitting.

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 Shaper. 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 all available Bosch 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

MA 201	Mathematics - III	BSC	3 - 0 - 0	3 Credits

Pre-requisites: MA151-Mathematics - II

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	Understand and use of complex variables and evaluation of real integrals

Mapping of course outcomes with program outcomes:

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	2	2	-	-	-	-	-	-	-	-	-	-	1	1	-	-
CO2	2	2	-	-	-	-	-	-	-	-	-	-	1	1	-	-
CO3	2	2	-	-	-	-	-	-	-	-	-	-	1	1	-	-
CO4	2	2	-	-	-	-	-	-	-	-	-	-	1	1	-	-

Detailed 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.

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.

Complex Variables: Analytic function - Cauchy Riemann equations - Harmonic functions - Conjugate functions - complex integration - line integrals in complex plane - Cauchy's theorem (simple proof only), Cauchy's integral formula - Taylor's and Laurent's series expansions -

zeros and singularities - Residues - residue theorem, use of residue theorem to evaluate the real integrals of the type $\int_{0}^{2\pi} f(Cos\theta, Sin\theta)\, d\theta$, $\int_{-\infty}^{\infty} f(x)dx$

without poles on the real axis.

Reading:

1. R.K.Jain and S.R.K.Iyengar, *Advanced Engineering Mathematics,* Narosa Pub. House, 15^{th} Edition, 2016.
2. ErwynKreyszig, *Advanced Engineering Mathematics*, John Wiley and Sons, 8^{th} Edition, 2008.
3. B.S.Grewal, *Higher Engineering Mathematics*, Khanna Publications, 44^{th} Edition, 2017.

MM201	Physical Metallurgy	PCC	3-0-0	03

Pre-requisites: PH101-Engineering Physics, CY101-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 Fe-C based binary and ternary phase diagrams.
CO4	Apply theory of diffusion in materials.
CO5	Describe principles and applications of optical and electron microscopes.

Mapping of course outcomes with program outcomes

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	3	1	-	-	-	-	-	-	-	-	-	-	-	1	-	1
CO2	3	-	-	-	-	-	-	-	-	-	-	-	-	2	-	
CO3	3	2	-	-	-	-	-	-	-	-	-	-	-	2	-	1
CO4	3	-	-	-	-	-	-	-	-	-	-	-	-	2	-	
CO5	2	-	-	2	2	-	-	-	-	-	-	-	-	2	-	3

Brief Syllabus:

Crystal structure of metals, Packing factor and density calculation of structures, Miller Indices, Types of voids, Crystallographic defects. Alloying concept, Hume Rothery Rules. Construction of equilibrium diagrams, Isomorphous systems, Lever rule, Coring, Congruent melting, Eutectoid, Peritectic, Peritectoid, Monotectic and Syntectic reactions, Binary and Ternary phase diagrams, Phase rules. Fick's law of diffusion, Kirkendall effect, Atomic theory of diffusion. Nucleation and Growth Kinetics, Application of Heterogeneous Nucleation. Construction of Optical and Electron Microscope and their applications.

Detailed 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-Fe_3C, 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, other diffusion processes.

NUCLEATION KINETICS:

Homogeneous nucleation, Rate of homogeneous nucleation, Growth rate equation, Heterogeneous Nucleation, Application of Nucleation theory in Phase Transformations.

MICROSCOPY:

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

Reading:

1. S. H. Avner, Introduction of Physical Metallurgy, Mc Graw Hill 2nd Edition, 1987.
2. V. Raghavan, Materials Science and Engineering, Prentice Hall, 4th Edition, New Delhi, 1999.
3. R E. Hill and Abbaschain, Physical Metallurgy Principles, PWS Publishing Company, 2nd Edition, 1994.
4. D S Clark and W. R. Varney, Physical Metallurgy for Engineers, CBS Publications, 1st Edition, New Delhi, 1979.

MM202	Unit Processes in Extractive Metallurgy	PCC	3-1-0	4 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

Mapping of course outcomes with program outcomes

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	3	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-
CO2	3	2	-	-	-	-	-	-	-	-	-	-	1	-	-	-
CO3	2	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-
CO4	2	-	2	-	-	-	-	-	-	-	-	-	2	-	-	-

Brief Syllabus:

Scope of extractive metallurgy, occurrence of metals in nature, minerals and ores. Elementary concepts of Mineral processing and extraction of metals. Pyrometallurgy: Drying and calcination, roasting and derivation of roasting conditions by Kellog's diagram, relevance of Ellingham diagram in metal extraction, smelting and converting, metal refining processes. Hydrometallurgy: Leaching and its methods, construction and use of Pourbax diagram, bioleaching, solution purification and concentration. Recovery of metals from leach solutions. Electrometallurgy: Principles of electrolysis, electrolytic systems, electro-refining, electrowinning.

Detailed 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.

Reading:

1. C. K. Gupta, Chemical Metallurgy: Principles and Practice, John Wiley & Sons, 2006.
2. R. H. Parkar: An Introduction to Chemical metallurgy, Pergamon, 1983.
3. M. Shamsuddin, Physical Chemistry of Metallurgical Processes, Wiley, 2016.
4. J. J. Moore: Chemical Metallurgy, Butterworth & Co., 1990.
5. E. J. Pryor, Mineral Processing, Elsevier, 1985.
6. R.D. Pehlke, Unit Processes in Extractive Metallurgy, Elsevier, 1973.
6. T. Rosenqvist, Principles of Extractive Metallurgy, McGraw Hill, 2004.
8. H.S. Ray and A. Ghosh, Principles of Extractive Metallurgy, New Age International Publishers, 1991.
9. H. S. Ray, R. Sridhar and K.P. Abraham, Extraction of Non-ferrous Metals, Affiliated East West, 1985.
10. F. Habashi, Principles of Extractive Metallurgy, Vol. 1-4, McGraw-Hill, 1993.

MM203	Metallurgical Thermodynamics	PCC	3-1-0	4 Credits

Pre-requisites: MA151-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.

Mapping of course outcomes with program outcomes

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	3	1	-	-	-	-	-	-	-	-	-	-	1	1	-	-
CO2	2	3		-	-	-	-	-	-	-	-	-	2	2	-	-
CO3	-	-	2	-	-	-	-	-	-	-	-	-	1	1	-	-
CO4	-	1	3	-	-	-	-	-	-	-	-	-	-	2	-	-

Brief Syllabus:

Thermodynamic foundations, Laws of thermodynamics, Concept of reversibility, internal energy, enthalpy, entropy, free energy, Maxwell's relations and Gibbs-Helmholtz equation, Clausius-Clapeyron equation, Fugacity, Activity and Equilibrium constant, Concept of chemical potential, Phase rule, Solution thermodynamics, Gibbs-Duhem equation, Thermodynamic properties of binary solutions, ideal, non-ideal and regular solutions, Activity coefficient, Concept of partial molal properties, Thermodynamics of electro-chemical cells, Applications of Gibbs-Helmholtz equation, Chemical kinetics- theories of kinetics, Arhenius equation, Activation energy, molecularity and order, catalysis.

Detailed Syllabus:

Thermodynamic foundations: 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, reversible and non-reversible process, 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 and applications. 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.

Thermodynamics of electro-chemical cells: Galvanic cells, Relation between chemical and electrical energy,Nernst equation, Standard EMF of a cell, Sign convention, Standard potentials, oxidation-reduction potentials, Applications of Gibbs-Helmholtz equation to galvanic cells, Concentration cells, Reference electrodes, Applications of EMF cells.

Chemical Kinetics: Kinetics of chemical processes, effect of temperature on reaction rate, Collision theory and theory of absolute reaction rates, Activation energy and its determination, Molecularity and Order of a reaction, Determination of order of a reaction, Half-life period, Catalysis in chemical reactions.

Reading:

1. D. R. Gaskell, Introduction to Thermodynamics of Materials, Taylor and Francis, 2003.
2. Lawrence S. Darken & Robert W. Gurry, Physical Chemistry of Metals, CBS Publishers & Distributors-Delhi, 2002
3. J. Mackowiak, Physical Chemistry for Metallurgists, © George Allen & Unwin Ltd., Pitman Press, Bath, 1965
4. M. L. Kapoor, Chemical and Metallurgical Thermodynamics, Vol. 1&2, Nem Chand & Bros, Roorkee, 1981
5. Balluffi R.W., Allen S.M. and Carter W.C., Kinetics of Materials, John Wiley and Sons. 2005
6. A. Ghosh, Text Book of Materials and Metallurgical Thermodynamics, Prentice Hall of India Pvt. Ltd., 2003.

7. C.H.P. Lupis, Chemical Thermodynamics of Materials Published by Elsevier Science Ltd, 1983
8. SveinStølen, Tor Grande, Neil L. Allan, Chemical Thermodynamics of Materials - Macroscopic and Microscopic Aspects, John Wiley & Sons Ltd., 2004.
9. R.A. Swalin, Thermodynamics of Solid by, John Wiley & Sons, NY, 1962

MM204	Transport Phenomena	DPC	3-0-0	3 Credits

Prerequisite: MA151-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.

Mapping of course outcomes with program outcomes

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	3	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-
CO2	1	-	3	-	-	-	-	-	-	-	-	-	-	3	-	-
CO3	-	3	-	-	-	-	-	-	-	-	-	-	3	-	-	-
CO4	-	2	3	-	-	-	-	-	-	-	-	-	2	2	-	-

Brief syllabus: Introduction to transport phenomena, dimensional analysis, properties of fluids, kinetic theory of gases and liquids, types of fluid flow, shell momentum balances, equation of continuity, Navier stokes equation and its applications, friction factor calculations, Bernoulli's equation and its applications in fans, pumps, compressors, Fourier's law of heat conduction, steady/ unsteady state heat transfer, natural and forced convection, heat transfer during solidification and phase transformation, radiation heat transfer, mass diffusion, Darken'sequation, Kirkendall's effect, application of mass transfer in carburization, similarities of momentum, heat and mass transfer.

Detailed syllabus:

Introduction to Transport phenomena, Units and Dimensional Analysis. 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

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.

iffusivity 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.

Reading:

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, 201
6. Julian Szekely, Fluid Flow Phenomena in Metals Processing, Academic Press Inc., 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**	**0-0-2**	**02**

Pre-requisites: None

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

CO1	Prepare crystal models.
CO2	Prepare ferrous and non-ferrous samples for metallography.
CO3	Use metallurgical microscope to observe microstructures of steels, cast iron and nonferrous alloys
CO4	Determine the grain size, shape and volume fraction of phases.

Mapping of course outcomes with program outcomes

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**	**PSO 1**	**PSO 2**	**PSO 3**	**PSO 4**
CO1	1	-	-	-	-	-	-	-	1	-	-	1	-	1	-	-
CO2	-	2		2	-	-	-	-	-	-	-	-	-	-	-	3
CO3	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	3
CO4	-	3	-	-	-	-	-	-	-	2	-	-	-	-	-	3

Brief syllabus

Crystal Models, Planes, Directions, Study of Metallurgical Microscope, Metallographic Preparation of Ferrous & Non-ferrous samples, Microstructure of Pure Metals, Plain Carbon Steels, Cast Irons, Construction and Study of Phase Diagrams.

Reading:

1. Introduction of Physical Metallurgy, Mc Graw Hill, 2017- S. H. Avner.
2. Materials Science and Engineering, Prentice Hall, 4th Edition, New Delhi, 1999 - V. Raghavan.

MM206	Unit Processes in Extractive Metallurgy Laboratory	PCC	0-1-2	02 Credits

Pre-requisites: None

CO1	Carry out suitable unit process for extraction of metals
CO2	Perform suitable concentration technique for leach solution
CO3	Carryout electro deposition of metals
CO4	Identify techniques for recovery of metals from leach solutions

Mapping of course outcomes with program outcomes

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	-	-	-	-	3	-	-	-	-	-	-	-	3	-	-	-
CO2	-	-	-	-	3	-	-	-	-	-	-	-	3	-	-	-
CO3	-	-	-	-	3	-	-	-	-	-	-	-	3	-	-	-
CO4	-	-	2	-	-	-	-	-	2	2	-	-	3	1	-	-

Illustrative List of Experiments:

1. Roasting of sulphides
2. Reduction of oxides
3. Smelting of sulphide/oxide ores
4. Leaching of oxide ores
5. Solvent extraction
6. Effect of current density on deposition of copper.
7. Throwing power of Nickel sulphate/Copper sulphate bath
8. Cementation
9. Anodizing of Aluminium
10. Deposition of Chromium.

EE235	Basic Electrical Engineering Laboratory	ESC	0–0– 3	2 Credits

Pre-requisites: None

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

CO1	Select the range of apparatus based on the ratings of DC machines, transformers and induction machines.
CO2	Understand the operation of KVL, KCL and Superposition theorems applied to simple dc circuits.
CO3	Determine equivalent circuit parameters of transformers by conducting OC and SC tests.
CO4	Evaluate the performance of dc machines and its braking methods.
CO5	Evaluate the performance of asynchronous machines by no-load test, blocked rotor test and load test.

Mapping of course outcomes with program outcomes

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
CO2	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
CO3	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
CO4	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
CO5	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1

Detailed syllabus

a) Verification of Kirchhoff’s Voltage and Current Laws.

b) Verification of Superposition Theorem.

Calculation of the Power factor and Power in a Single Phase Series R-L circuit.

Measurement of Self and Mutual inductance of Coils.

No load test on a DC Machine.

Load test on a DC Shunt Generator.

Speed Control of a DC Shunt Motor

MA251	MATHEMATICS IV	BSC	3– 0 – 0	3 Credits

Pre-requisites: MA201-Mathematics III

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

CO1	Interpret an experimental data using interpolation / curve fitting
CO2	Solve numerically algebraic/transcendental and ordinary differential equations
CO3	Understand the concepts of probability and statistics
CO4	Obtain the series solutions for ordinary differential equations

Mapping of course outcomes with program outcomes

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	-	3	-	1	-	-	-	-	-	-	-	-	-	-	-	1
CO2	-	3	-	1	-	-	-	-	-	-	-	-	-	-	-	1
CO3	-	3	-	1	-	-	-	-	-	-	-	-	-	-	-	1
CO4	-	3	-	1	-	-	-	-	-	-	-	-	-	-	-	1

Detailed Syllabus:

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.

Probability and Statistics: Random variables, discrete and continuous random variables, Mean and variance of Binomial, Poisson and Normal distributions and applications.

Testing of Hypothesis – Null and alternate hypothesis, level of significance and critical region - Z-test for single mean and difference of means, single proportion and difference of proportions - t-test for single mean and difference of means - F-test for comparison of variances, Chi-square test for goodness of fit - Karl Pearson coefficient of correlation, lines of regression and examples.

Series Solution: Series solution of Bessel and Legendre's differential equations - Bessel function of first kind, Recurrence formulae, Generating function, Orthogonality of Bessel functions - Legendre polynomial, Rodrigue's formula, Generating function, Recurrence formula, Orthogonality of Legendre polynomials.

Reading:

1. M. K. Jain, S.R.K.Iyengar and R.K.Jain, Numerical methods for Scientific and Engineering Computation, New Age International Publications, 2008.
2. S.C.Gupta and V.K.Kapoor, Fundamentals of Mathematical Statistics, S.Chand & Co, 2006.
3. Erwyn Kreyszig, Advanced Engineering Mathematics, John Wiley and Sons, 8th Edition, 2008.
4. B.S.Grewal, Higher Engineering Mathematics, Khanna Publications, 2009.

MM251	Phase Transformations and Heat Treatment	PCC	3-1-0	04 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 / 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	3	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-
CO2	-	-	3	-	-	-	-	-	-	-	-	-	-	3	1	-
CO3	1	-	3	-	-	-	-	-	-	-	-	-	-	-	2	-
CO4	-	-	3	-	-	-	-	-	-	-	-	-	-	1	3	-

Brief Syllabus:

Concept of Phase Transformations, Application of Phase Transformations in Materials Engineering, Study of Fe-Fe_3C Phase Diagram, Determination of Grain Size, Isothermal Transformation Diagrams, Pearlite, Bainite and Martensitic Transformations, Transformation of Austenite on Continuous Cooling, Annealing, Normalizing, Hardening and Tempering of steels, Hardenability, Quenching Process and media, Martempering and Austempering, Heat Treatment of Alloy Steels, Types and Application of Cast Irons, Heat Treatment of Cast Irons, Flame and Induction Hardening, Laser beam Hardening (LBM), Carburizing, Nitriding, Cyaniding, Theory of Age Hardening, Study of Age Hardened Alloys.

Detailed Syllabus:

PHASE TRANSFORMATIONS:

Phase Transformations of Materials, Application of Nucleation and Growth concept in Phase Transformations, Study of Fe-Fe_3C 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.

Reading:

1. D. A. Porter and K. E. Easterling, Phase Transformation in Metals and Alloys, VNR International, 2nd Edition, 1992.
2. Y. Lakhtin, Engineering Physical Metallurgy, Mir Publishers, 6th Edition1997.
3. S. H. Avner, Introduction of Physical Metallurgy, Mc Graw Hill 2nd Edition, 1987.
4. V. Raghavan, Materials Science and Engineering, Prentice Hall, 4th Edition, New Delhi, 1999.

MM252	**Solidification Processing**	**PCC**	**3-1-0**	**04 credits**

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

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 morpho-genesis 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

Mapping of course outcomes with program outcomes

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**	**PSO 1**	**PSO 2**	**PSO 3**	**PSO 4**
CO1	3	-	2	-	-	-	-	-	-	-	-	-	-	2	-	-
CO2	-	2	2	-	-	-	-	-	-	-	-	-	-	2	-	-
CO3	-	-	3		1	-	-	-	-	-	-	-	-	-	2	-
CO4	-	3	3	2`	-	-	-	-	-	-	-	-	3	-	-	1
CO5	-	2	-	-	-	-	-	-	-	-	-	-	-	-	2	-

Brief Syllabus:

Thermodynamics of solidification, Nucleation and growth, Solidification of pure metals and alloys. Scheil equation, Constitutional undercooling, Mullins-Sekerka instability, Dendrite growth, Multi phase solidification: eutectic and peritectic, Structure of casting and ingots. Principles of pattern making and mould making. Types of castings. Design of gating and risering. Casting Defects. Melting furnaces. Melting and solidification of cast irons and aluminium. Solidification, heat transfer and fluid flow during fusion welding.

Detailed syllabus:

Thermodynamics of solidification: pure metal solidification i.e. G vs T curves for liquid and solid, alloy solidification. Scheil equation: Mathematical analysis of redistribution of solute during directional solidification, Microsegregation, Constitutional undercooling, Theories of nucleation and growth: Mullins-Sekerka instability, Ivantsov's theory of dendritic growth, Multi phase solidification: regular and irregular eutectic solidification, Hunt-Jackson theory of eutectic growth, peritectic growth, Structure of casting and ingots, Types of casting, Heat transfer, design of riser and gating. Solidification, heat transfer, fluid flow during fusion welding. Casting Defects. Melting furnaces. Melting and solidification of cast irons and aluminium. Solidification, heat transfer and fluid flow during fusion welding.

Reading:

1) Kurz and Fisher: Solidification Processing, Trans Tech publications 1998.

2) R. W. Heine, C. R. Loper, P. C. Rosenthal: Principles of metal casting, Mc Graw Higher Ed 1976.

3) K. Easterling: Introduction to physical metallurgy of welding, Butterworth-Hienemann 1992.

4) P. K. Jain: Principles of foundry technology, Mc Graw-Hill 1987.

MM253	**Iron Making Technology**	**PCC**	**3-0-0**	**03 Credits**

Pre-requisites: MM203-Metallurgical Thermodynamics

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

CO1	Explain raw materials and basic principles of iron making.
CO2	Discuss the extraction technique of pig iron by reduction smelting in blast furnace from iron ores.
CO3	Describe the physico-chemical processes occurring in a blast furnace
CO4	Suggest alternate routes of iron making.

Mapping of course outcomes with program outcomes

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**	**PSO 1**	**PSO 2**	**PSO 3**	**PSO 4**
CO1	3	2	-	1		-	-	-	-	-	-	-	3	-	-	-
CO2	3	-	-		2	-	-	-	-	-	-	-	3	2	-	-
CO3	3	2	-	-	-	-	-	-	-	-	-	-	3	1	-	-
CO4	3	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-

Detailed syllabus:

History of Ironmaking: Importance of Iron and Steel for the modern society, Introduction to pig iron production India and the world, Developments that led to modern ironmaking.

Preparation of burden materials: Introduction, Iron ore deposits in India and the world. Metallurgical coal, Limestone and Dolomite, Coke: functions, quality requirements such as reactivity, size, strength and abrasion resistance, micum test, ASTM tumbler test, coke reactivity test and coke strength after reaction. Sintering: principle, process variables, and mechanism of sintering, recent trends in sintering practice. Pelletization: principle, theory of bonding, mechanism of ball formation, disc pelletizer, drum pelletizer, induration of pellets, process variables in pelletization, recent trends in pelletization process, Nodulization.

Testing of Burden materials: Introduction, shatter test, tumbling and abrasion test, compression test at room and high temperatures, porosity, reducibility, decrepitation, low-temperature breakdown test, reduction degradation index test, reducibility index test.

Blast Furnace principles and operation: Introduction, construction of blast furnace and its accessories such as blast furnace stoves and gas cleaning system. Thermal, physical and chemical profiles, equilibria in C-O, Fe-C-O, Fe-O-H systems, kinetics of iron oxide reduction. Reactions at various zones: stack, bosh, belly, tuyere and hearth zones. Operational procedures in blast furnace: drying, filling, lighting, banking, blowing out, tapping, fanning, back drafting. Irregulaties in blast furnace: hanging, scaffolding, slip, chilled hearth, pillaring, breakout, choking of gas offtake, flooding and coke ejection, channeling and salamander formation. Impact of burden distribution on the blast furnace performance.

Modern trends in Blast furnace design and practice: Large-capacity blast furnaces, modifications in top charging system, stockline armor and high top pressure. Utilization of raw materials: coke quality, burden preparation and improved distribution of charge, lime injection, pulverized coal injection, utilization of plant iron-bearing wastes. Modifications to the Blast: higher blast temperature and driving rate, oxygen enrichment, humidification and fuel injection. Efficient operational control.

Alternate routes of iron production: Low shaft furnace, mini-blast furnaces, submerged arc furnace. Sponge iron production: Rotary kiln process, rotary hearth furnace based processes, HYL processes, Midrex process, fluidized bed processes. Uses of sponge iron. Smelting reduction processes: fundamentals, Elred process, Inred process, Corex process, Finex process, Fastmelt process, Hismelt process, Cleansmelt process, Cyclone converter furnace process, Plasmasmelt process.

Reading:

1. R.H. Tupkary, V.R. Tupkary, Modern Iron making handbook, MLI Handbook Series, 2017.
2. C. Bodsworth, Physical Chemistry of Iron and Steel manufacture, Metallurgy and Metallurgical Engineering Series, 2014.
3. David H. Wakelin, Richard J. Fruehan, The making, shaping and treating of steel: Iron making volume, 11th edition, AISE steel foundation, 1999.
4. Amit Chatterjee, Sponge iron production by direct reduction of iron oxide, PHI learning private limited, 2010.
5. Arabinda Sarangi, Bidyapati Sarangi, Sponge iron production by rotary kiln, PHI learning private limited, 2011.
6. Amit Chatterjee, Hot metal production by smelting reduction of iron oxide, PHI learning private limited, 2010.

MM254	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	Describe the origin of magnetism and types of conventional and advanced magnetic materials
CO2	Mention the basics of semi-conductors, superconductors, and classify them
CO3	Classify the dielectric materials and state their theories
CO4	List the types of vacuum devices used for manufacturing electronic and magnetic materials
CO5	Introduce the manufacturing techniques of Si-based electronic materials

Mapping of course outcomes with program outcomes

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	3	-	-	-	2	-	-	-	-	-	-	-	-	-	2	-
CO2	3	-	-	-	2	-	-	-	-	-	-	-	-	-	2	-
CO3	3	-	-	-	2	-	-	-	-	-	-	-	-	-	2	-
CO4	3	-	-	-	2	-	-	-	-	-	-	-	-	-	2	-

Detailed syllabus

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.

Semiconducting and Superconducting Materials:

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 resistance, Type I and II superconductors, Critical field, Meissner-Effect, High temperature Superconductors, BCS Theory, YBCO & Bi-2212 – Crystal structure and Preparation methods, Applications-Persistent current, Levitation, Flux quantization, Josephson junction, SQUID.

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.

High Vacuum Techniques

Introduction to vacuum devices. Rotary pump, Diffusion pump, turbo-molecular pump, Ion-pump, Measurement of vacuum – Pirani gauge, Penning gauge and McLeod gauge – Basic vacuum system assembly and sequence of operation to create high vacuum.

Crystal Growth and Photovoltaics:

Siemens process to obtain electronic grade silicon, Growth of single crystals by Czochralski technique, Silicon wafer preparation for electronic devices (slicing & polishing). Techniques involved in preparation of electronic chip. Photovoltaic effect, Types of silicon solar cells (amorphous, poly & single crystal), Fabrication and functioning of silicon solar cells.

Reading:

1. B. D. Cullity, C.D. Graham, 2nd Ed., Introduction to Magnetic Materials, Wiley and IEEE, 2009

2. S.M. Sze: VLSI Technology, McGraw Hill International Edition, 2009.

3. Charles Kittel: Introduction to Solid State Physics, Wiley, 2007.

4. J D Patterson: Solid State Physics, 2nd Edition, Springer, 2011.

5. D.M. Hoffman, B. Singh, J.H. Thomas, Handbook of Vacuum Science and Technology, Academic Press 1998.

6. David Jiles, Introduction to Magnetism & Magnetic materials, London: Chapman & Hall, 1998.

7. Milton Ohring, Materials Science of Thin Films, Academic Press, San Diego, 2002.

MM255	Phase Transformations and Heat Treatment Laboratory	PCC	0-1-2	02 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.

Mapping of course outcomes with program outcomes

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	-	-	-	2	3	-	-	-	3		-	-	-	3	-	1
CO2	-	-	-	-	3	-	-	-			-	-	-	-	-	3
CO3	-	-	-	3	2	-	-	-		2	-	-	-	-	-	2
CO4	-	3	-	`-	-	-	-	-	2	2	-	-	-	-	-	3

Brief syllabus

Grain size measurement & Calculation of Volume fraction of Phases, Microstructure of Steels and Composites, Microstructure of Annealed, Normalising, Hardened samples, Tempering, Jominy End Quench Test and Scanning Electron Microscopy (SEM) Study of Different Samples

Readings:

1. Introduction of Physical Metallurgy, Mc Graw Hill, 2017- S. H. Avner.
2. Alloy Phase Diagrams, ASM Handbook, Volume 3.

MM256	Solidification Processing Laboratory	PCC	0 – 1 – 2	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	Use simulating software to study casting processes

Mapping of course outcomes with program outcomes

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	-	-	-	3	1	-	-	-	-	-	-	-	-	-	1	3
CO2	-	-	-	-	3	-	-	-	3	-	1	-	-	-	3	-
CO3	-	-	-	-	3	-	-	-	3	-	-	-	-	-	3	-
CO4	-	-	-	-	3	-	-	-	3	-	-	-	-	-	3	-
CO5	-	3	-	-	3	-	-	-		3	-	-	-	-	2	-

List of experiments:

Sand Testing: Green and dry strength testing, Determination of permeability, Shatter index, clay content, Moisture content, cured transverse strength of shell sands.
Mould preparation:
Demonstration of Melting and casting: Casting of metals using induction furnace, casting of metals using vacuum arc melting furnace, casting of metals using resistance heating furnace.

Casting software: Use PROCAST software to study solidification behavior.

Reading:

Lab manual

EC286	Basic Electronics Laboratory	PCC	0 – 0 – 3	2 Credits

Pre-requisites: None

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

CO1	Develop and employ circuit models for elementary electronic components using diodes, transistors, and operational amplifier.
CO2	Design simple circuits containing non-linear elements (transistors) using the concepts of load lines, operating points and incremental analysis.
CO3	Calculate frequency response curves of single stage BJT amplifier and determine bandwidth of the amplifier.
CO4	Demonstrate binary functions electronically using Diodes, BJTs and JFET's
CO5	Build and trouble-shoot simple electronic analog and digital circuits

Mapping of course outcomes with program outcomes

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
CO2	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
CO3	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
CO4	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
CO5	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1

Detailed syllabus

Characteristics of PN junction Diode
Load regulation characteristics of Zener diode
Rectifiers & Filters.
Characteristics of BJT
Characteristics of JFET
Single stage Amplifier.
R.C. Phase shift oscillator.
Clippers and Clampers.
Op-amp Frequency Response
Verification of Logic Gates.

Reading

Basic Electronics Laboratory Manual

SM355	Engineering Economics	HSC	3-0-0	03 Credits

Prerequisite: None

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

CO1	Prepare accounting records and summarize and interpret the accounting data for managerial decision
CO2	Understand the Macro economic environment of business and its impact on enterprise
CO3	Understand cost elements of the product and its effect on decision making
CO4	Understand the concepts of financial management and smart investment
CO5	To develop effective presentation skills

Mapping of course outcomes with program outcomes

PO / CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO7	PO8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2	PSO 3	PSO 4
CO1	-	-	-	-	-	-	-	-	-	2	2	2	-	-	-	-
CO2	-	-	-	-	-	-	-	-	-	2	2	2	-	-	-	-
CO3	-	-	-	-	-	-	-	-	-	2	2	2	-	-	-	-
CO4	-	-	-	-	-	-	-	-	-	2	2	2	-	-	-	1

Detailed Syllabus:

Engineering Economics

1. Introduction to Engineering Economics, Fundamental concepts, Time value of money, Cash flow and Time Diagrams, Choosing between alternative investment proposals, Methods of Economic analysis (Pay back, ARR, NPV, IRR and B/C ratio),
2. The Effect of borrowing on investment, Equity Vs Debt Financing, Concept of leverage, Income tax and leverage
3. Depreciation and methods of calculating depreciation (Straight line, Sum of the years digit method, declining Balance Method, Annuity Method, Sinking Fund method).
4. National Income Accounting, Methods of Estimation, Various Concepts of National Income, Significance of National Income Estimation and its limitations.
5. Inflation, Definition, Process and Theories of Inflation and Measures to Control,

6. New Economic Policy 1991 (Industrial policy, Trade policy, and Fiscal policy) Impact on Industry

Accountancy

1. Accounting Principles, procedure, Double entry system, Journal, ledger, Trial balance, Cash Book Preparation of Trading and Profit and Loss account, Balance Sheet,
2. Cost Accounting, Introduction, Classification of costs, Methods of Costing, Techniques of Costing, Cost sheet and preparation cost sheet, Breakeven Analysis, Meaning and its application, Limitation.

Presentations/ Group Discussions on current topics.

Text Books/Reference:

1. Henry Malcom Steinar-Engineering Economics Principles, McGraw Hill Pub. (For Topic 1, 2, 3)

2. Dewett K.K., “Modern Economic Theory”, Sultan Chand & Co. (Topics 4, 5)

3. Agrawal AN, “Indian Economy” Wiley Eastern Ltd, New Delhi (Topic 6)

4. Jain and Narang” Accounting Part-I”, Kalyani Publishers (Topic 7)

5. Arora, M.N.” Cost Accounting, Vikas Publication. (Topic 8)

MM301	Steel Making Technology	PCC	3-0-0	03 Credits

Pre-requisites: MM253-Iron Making Technology

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

CO1	Explain basic principles of steel making.
CO2	Differentiate open hearth, Bessemer, LD and Q-BOP steel making processes
CO3	Describe the secondary refining techniques of steel making.
CO4	State the principle of continuous casting of steel.

Mapping of course outcomes with program outcomes

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	3	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-
CO2	3	-	-	-	1	-	-	-	-	-	-	-	3	-	-	-
CO3	3	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-
CO4	3	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-

Brief syllabus

History of steelmaking in India and the world, thermodynamics and kinetics in steelmaking, conventional steelmaking practices: Bessemer process and open hearth process; basic oxygen steelmaking processes: LD process, OBM process, Rotating BOF processes and hybrid processes; steelmaking by electric arc furnace and induction melting process, secondary steelmaking processes: deoxidation process, ladle metallurgy, injection metallurgy, AOD, VOD, CLU, MRP, SR-KCB processes, VAR & ESR processes; tundish metallurgy, ingot casting process, continuous casting process, modelling in iron and steelmaking.

Detailed syllabus

History of steelmaking: steelmaking in India: yesterday, today and tomorrow, Environmental, health and safety issues in the steelmaking industry.

Thermodynamic and kinetic aspects in steelmaking: Thermodynamical aspects in steelmaking: chemical equilibrium, concentrated and dilute liquid solutions, activity constants, chemical potential. Mechanisms of heat transfer in steelmaking. Kinetics of gas-liquid, liquid-liquid and liquid-solid reactions. Slags: Molecular theory, Ionic theory, Oxidizing power, Capacities of slags, slag engineering and slag foaming operation.

Conventional and modern steelmaking: Introduction to Bessemer process and open hearth processes. LD process: construction, operation, modern trends. Rotating basic oxygen furnace processes: Kaldo, LD-Kaldo and rotor processes. OBM process: construction, mechanism and operational details. Modern basic oxygen furnace processes. Steelmaking by electric arc furnace: construction, operation and modern trends. Slagless steelmaking. Energy optimizing furnace.

Secondary steelmaking processes: Basics of fluid flow, fluid flow in steel melts, mixing, mass transfer and kinetics. Removal of gases in liquid steel: Thermodynamic and kinetic principles, deoxidation, vacuum degassing practices in steel industry. External desulfurization and dephosphorization. Ladle Metallurgy, Injection metallurgy and tundish metallurgy. Principle of inclusion engineering and production of clean steels.

Casting processes: Ingot casting: process, operation and ingot defects. Continuous casting: process flow description, casting products, casting defects, trends in continuous casting, electro-magnetic stirring and braking, thin slab casting and strip casting.

Reading:

1. R.H. Tupkary, V.R. Tupkary, An introduction to modern steel making, Khanna publishers, 2014.
2. Ahindra Ghosh and Amit Chatterjjee, Ironmaking and steelmaking: Theory and practice, PHI learning private limited, 2008.
3. Richard J. Fruehan, The making, shaping and treating of steel, 11th Edition, American Society for Metals, 1998.
4. Ahindra Ghosh, Secondary steelmaking: principles and applications, CRC press, 2001.
5. Dipak Mazumdar, James W. Evans, Modeling of steelmaking processes, CRC press, 2010.

MM302	Mechanical Behaviour of Materials	PCC	3-1-0	04 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

Mapping of course outcomes with program outcomes

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	3	-	-	-		-	-	-	-	-	-	-	-	2	-	-
CO2	3	-	-	-	2	-	-	-	-	-	-	-	-	-	-	3
CO3	3	-	1	-	-	-	-	-	-	-	-	-	-	2	-	-
CO4	3	-	-	`2	-	-	-	-	-	-	-	-	-	-	-	2

Detailed 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, Grain boundary strengthening, Hall-Petch Relation, Hall-Petch strengthening limit, Strengthening from second phase, Factors influencing second-phase particle strengthening, Solid Solutions 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, Fibre Strengthening, Martensitic strengthening, Ausforming Process, Strain hardening or cold working, Annealing of cold-worked metal-Recovery, Recrystallisation and Grain growth.

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, Poldi Hardness Test

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, Holloman power curve, Factors affecting shape and magnitude of stress-strain curve

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; Significance and Specialized test for transition temperature; 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, fatigue testing.

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. Creep test.

Reading:

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. Derek Hull and D.J. Bacon: Introduction to Dislocations, 5th Edition, Pergamon Press, 2013.
4. Thomas H. Courtney, Mechanical Behavior of Materials, 2nd Edition, McGraw Hill, New York, 2000.
5. M.A. Meyers and Chawla K, Mechanical Behavior of Materials, 2nd Edition, Cambridge University Press, 2009
6. Richard W. Hertzberg, Deformation and Fracture Mechanics of Engineering Materials, 5th Edition, John Wiley & Sons, New York, 2012

MM303	Powder Metallurgy	PCC	3 0 0	03

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.

Mapping of course outcomes with program outcomes

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	3	-	-	-	1	-	-	-	-	-	-	-	2	-	-	-
CO2	-	-	-	2	2	-	-	-	-	-	-	-	-	-	-	2
CO3	3	-	-	-	1	-	-	-	-	-	-	-	3	-	-	-
CO4	3	2	3	`	-	-	-	-	-	-	-	-	3	-	-	-
CO5	-	-	-	3	-	-	-	-	-	3		3	2	-	-	-

Detailed 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.

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).

Physical & Mechanical Properties Evaluation, 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.

Readings:

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

MM304	Mechanical Behaviour of Materials Laboratory	PCC	0-1-2	02 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	Suggest suitable equipment for determination of mechanical properties of bulk and sheet metal products

Mapping of course outcomes with program outcomes

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	-	-	-	-	3	-	-	-	2	-	-	-	-	-	-	3
CO2	-	2	-	-	3	-	-	-	2	-	-	-	-	-	-	3
CO3	3	-	-	-	3	-	-	-		-	-	-	-	-	-	3

Syllabus

Determination of Vickers, Brinell and Rockwell hardness; Poldi impact hardness; Shore Scleroscope hardness; Determination of n and k of given materials; Erichsen Ductility test, Standard impact tests: Charpy and IzodTest; Tensile/ Compression Test; Wear Test.

Readings:

1. Mechanical Behaviour of Materials Laboratory Manual

MM305	Powder Metallurgy Laboratory	PCC	0 0 2	02

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.

Mapping of course outcomes with program outcomes

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	3	-	-	-	2				2		-	-	-	-	2	-
CO2	2	-	-	-	3	-	-	-	-		-	-	-	-	-	2
CO3	2	-	-	-	3	-	-	-	-		-	-	-	-	3	-
CO4	2	-	-	-		-	-	-	-		-	-	-	-	3	-

Brief syllabus:

Compaction and Sintering of Different Powders, Wet Chemical Synthesis and Self-propagating High Temperature Synthesis (SHS) of Powder, Ball Milling, Characterization of Different Synthesized Powders, and Structure-Property correlation study of Sintered Samples

Readings:

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

MM311	FINITE ELEMENT METHOD	DEC	3 – 0 – 0	03 Credits

Pre-requisites: None

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

CO1	Explain the basics of finite element approach.
CO2	Solve one dimensional diffusion equation.
CO3	Solve for mechanical equilibrium to establish the stress and strain field in a component.
CO4	Apply crystal plasticity models to study deformation behavior of metals

Mapping of course outcomes with program outcomes

PO CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	3	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-
CO2	-	2	1	-	2	-	-	-	-	-	-	-	-	2	-	-
CO3	-	2	2	-	2	-	-	-	-	-	-	-	-	2	-	-
CO4	-	-	2	2	2	-	-	-	-	-	-	-	-	2	-	-

Detailed syllabus

Introduction: Historical Perspective of FEM and applicability to metallurgical and materials engineering problems.

Mathematical Models and Approximations: Review of elasticity, mathematical models for structural problems, Equilibrium of continuum-Differential formulation, Energy Approach-Integral formulation, and Principle of Virtual work - Variational formulation. Overview of approximate methods for the solution of the mathematical models; Ritz, Rayleigh-Ritz and Gelarkin's methods. Philosophy and general process of Finite Element method.

Finite Element Formulation: Concept of discretization, Interpolation, Formulation of Finite element characteristic matrices and vectors, Compatibility, Assembly and boundary considerations.

Finite element Method in One Dimensional Structural problems: Structural problems with one dimensional geometry. Formulation of stiffness matrix, consistent and lumped load vectors. Boundary conditions and their incorporation: Elimination method, Penalty Method, Introduction to higher order elements and their advantages and disadvantages. Formulation for Truss elements, Case studies with emphasis on boundary conditions and introduction to contact problems.

Beams and Frames: Review of bending of beams, higher order continuity, interpolation for beam elements and formulation of FE characteristics, Plane and space frames and examples problems involving hand calculations.

Two dimensional Problems: Interpolation in two dimensions, natural coordinates, Isoperimetric representation, Concept of Jacobian. Finite element formulation for plane stress plane strain and axis-symmetric problems; Triangular and Quadrilateral elements, higher order elements, subparametric, Isoparametric and superparametric elements. General considerations in finite element analysis of two dimension problems. Introduction plate bending elements and shell elements.
Three Dimensional Problems: Finite element formulation for 3-D problems, mesh preparation, tetrahedral and hexahedral elements, case studies.
Dynamic Analysis: FE formulation in dynamic problems in structures using Lagragian Method, Consistent and lumped mass models, Formulation of dynamic equations of motion and introduction to the solution procedures.
FEM in Heat Transfer and Fluid Mechanics problems: Finite element solution for one dimensional heat conduction with convective boundaries. Formulation of element characteristics and simple numerical problems. Finite element applications in one dimensional potential flows; Formulation based on Potential function and stream function.
Algorithmic Approach for problem solving: Algorithmic approach for Finite element formulation of element characteristics, Assembly and incorporation of boundary conditions. Guidelines for code development. Introduction to commercial FE packages.

Reading:

1. Seshu P, Textbook of Finite Element Analysis, PHI. 2004
2. Reddy, J.N., Finite Element Method in Engineering, Tata McGraw Hill, 2007.
3. SingiresuS.Rao, Finite element Method in Engineering, 5ed, Elsevier, 2012
4. Zeincowicz, The Finite Element Method for Solid and Structural Mechanics, 4th Edition, Elsevier 2007.

MM312	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	Describe the production of solid, liquid and gaseous fuels.
CO2	Classify the fuels and refractories and understanding their operating conditions.
CO3	Select fuels, and refractories to minimize the overall cost of production for a given application.
CO4	Illustrate the production, composition, properties, testing and applications of refractories.

Mapping of course outcomes with program outcomes

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	3	-	1	-	-	-	-	-	-	-	-	-	1	-	-	-
CO2	3	-		-	-	-	-	-	-	-	-	-	1	-	-	-
CO3	-	-	3	-	-	-	-	-	-	-	3	-	2	-	-	-
CO4	2	-	-	-`	2	-	-	-	-	-	-	-	-	-	-	2

Brief syllabus:

Solid fuels: Origin of coals, storage and pulverization of coal, Coke making, Testing of coke Liquid fuels: Petroleum refining, Cracking

Gaseous fuels: Producer gas, Water gas, Coke oven gas and Blast furnace gas

Comparison of Fuels: Solid, Liquid and gaseous fuels

Refractories: Classification of refractories, production, composition, properties, testing and application of common and special refractories

Selection of refractories: Refractories selection for metallurgical applications

Detailed syllabus:

Solid fuels: Origin of coals – types – properties – storage and pulverization of coal. Coke making by Beehive and byproduct coke ovens. Testing of coke, properties of coke for Blast furnace operation.

Liquid fuels: Principles of Crude petroleum refining, cracking.

Gaseous fuels: Manufacture, properties and uses of producer gas, water gas, coke oven gas and Blast furnace gas.

Comparison of Fuels: Solid, liquid and gaseous fuels

Refractories: Classification of refractories, production, composition, properties, testing and application of common refractories such as Silica, Fire clay, Magnesite, Chrome and Dolomite refractories, Special refractories.

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

Reading:

1. J. D. Gilchrist, Fuels, Furnaces and Refractories, Pergamon, 2001.
2. O. P. Gupta, Elements of Fuels, Furnaces and Refractories, Khanna Publishers, 1998.
3. W. Trinks and M. H. Mawhinney, Industrial Furnaces, John Wiley and Sons, 6^{th} Edition, 2003.

MM313	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.
CO2	Differentiate minerals beneficiation techniques.
CO3	Discuss the theory of settlement of particles.
CO4	Compute the recovery of ore mineral after concentration.

Mapping of course outcomes with program outcomes

CO \ PO	PO1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3	PSO4
CO1	3	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-
CO2	3	2	-	-	-	-	-	-	-	-	-	-	2	-	-	-
CO3	1	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
CO4	3	2	-	-	-	-	-	-	-	-	-	-	1	-	-	-

Detailed syllabus:

Introduction to the course, Scope and Objectives of Ore Dressing.

Sampling of ores by different methods – hand sampling, mechanical sampling, errors in sampling. Theory of liberation of minerals, 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.

Theories of comminution – Kick's, Rittinger's and Bond's theories.

Sizing - Sizing scales, laboratory sizing and reporting the data in various numerical and graphical forms, sedimentation, and elutriation. Industrial sizing units – Types of screen surfaces, Grizzlies, Trommels, Vibrating and Shaking screens. Mechanism of passing through a screening surface and effectiveness of a screen.

Movement of solids in Fluids, Stoke's and Newton's laws, Terminal velocity and its relation with size, relation between time and velocity, relation between distance traveled and velocity, Equal settling ratio, Free and hindered settling ratios.

Quantifying concentrating operations – Ratio of concentration, Recovery, Selectivity Index and Economic Recovery.

Classification: Principles, sizing and sorting classifiers, Study of Settling Cones, Rake Classifier, Spiral Classifier and Cyclones. Heavy Media Separation – Principles, flowchart, different media used, 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, Denver jig Baum jig, Hancock jig, James coal jig and Halkyln jig, Design considerations in 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.

Details about Indian ore dressing practices.

Reading:

1. Barry Wills, Tim Napier- Munn, Wills' Mineral Processing Technology, 4th edition, Elsevier, 2005
2. A. M. Gaudin, Principles of Mineral Dressing, Tata McGraw Hill, 1993.
3. S. K. Jain, Ore Processing, Oxford- IBH Publishing Company, 2005.
4. Anup Swain, Hemlatha Patra, G K Roy, Mechanical Operations, Tata McGraw Hill, 2010.
5. A. F. Taggart, Elements of Ore Dressing, John Wiley, NY, 1951.

MM314	POLYMER TECHNOLOGY	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Understand thermodynamics of polymer structures
CO2	Select polymerization reactor for a polymer product.
CO3	Characterize polymers.
CO4	State polymer additives, blends and composites.
CO5	Understand polymer rheology.
CO6	Identify suitable polymer processing methods

Mapping of course outcomes with program outcomes

PO / CO	PO 1	PO2	PO3	PO4	PO5	PO6	PO 7	PO 8	PO9	PO 10	PO 11	PO 12	PSO 1	PSO 2	PSO 3	PSO 4
CO1	3	-	-	-	-	-	-	-	-	-	-	-	-	1	2	-
CO2	3	-	2	-	-	-	-	-	-	-	-	-	-	-	3	-
CO3	-	-	2	-	3	-	-	-	-	-	-	-	-	-	-	3
CO4	3	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
CO5	3	-	-	2	-	-	-	-	-	-	-	-	-	-	2	-
CO6	-	2	2	-	-	-	-	-	-	-	-	-	-	-	3	-

Detailed Syllabus:

Introduction and Classification of Polymers. Thermosets, Factors influencing the polymer properties, Monomers used for polymer synthesis, synthesis procedure for monomers Styrene, ethylene, Vinyl monomers etc., Thermoplastics, Linear Branch, Cross Linked Polymers, Ewart Kinetics for emulsion polymerization.

Addition polymers – kinetics, synthesis and reactions, Condensation polymers, Kinetics reaction and processes, Polymerization Techniques - Emulsion polymerization and Suspension polymerization, Interfacial Polymerization with their merits

Molecular Weights, Polydispersity Index, Different Methods of determination of Molecular weight, Effect of Molecular weight on Engineering Properties of Polymers, Smith Ewart Kinetics for emulsion polymerization, Kinetics of free radical polymerization, Chain transfer agents, Kinetics of Step growth polymerization, Ziegler Natta polymerization Processes, Differentiation based on kinetics of Anionic and cationic polymers.

Polymerization reactors types and mode of operation, Polymerization reactor design, control of polymerization, Post polymerization unit operations and unit processes

High Performance and Specialty Polymers, Polymer additives, compounding. Fillers, plastisizers, lubricants, colourants, UV stabilizers, fire retardants and antioxidants.

Impact, flexural tensile testing methods of polymers, Mechanical Properties of Polymers, Thermodynamics of Polymer Mixtures, ASTM and ISO methods for testing of polymers.

Polymer processing: Extrusion process, Twin and Single Screw extrusion, Blow moulding, injection moulding, Wet and Dry spinning processes, thermo set moulding. Processing of polymer nanocomposites.

Manufacturing of polymers: flow-sheet diagrams, properties & applications of PE, PP, PS, Polyesters, Nylons, ABS and PC.

Reading:

1. Fried J R, Polymer Science and Technology, Prentice Hall of India Pvt. Ltd., New Delhi, Eastern Economy Edition, 2000.
2. Premamoy Ghosh, Polymer Science and Technology, 3rd Edition, Tata Mc. Graw-Hill Publishing Company, New Delhi, 2010.
3. R. Sinha, Outlines of Polymer Technology: Manufacture of Polymers, Prentice Hall of India Pvt. Ltd., NewDelhi, 2002.

MM315	Theory of Metallurgical Processes	DEC	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	Explain the techniques of extraction.
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.

Mapping of course outcomes with program outcomes

PO / CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO1 1	PO 12	PSO 1	PSO 2	PSO 3	PSO 4
CO1	3	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-
CO2	3	2	-	-	-	-	-	-	-	-	-	-	2	2	-	-
CO3	3	2	-	-	-	-	-	-	-	-	-	-	-	2	-	-
CO4	3	3	3	-	-	-	-	-	-	-	-	-	3	2	-	-

Brief Syllabus:

Introduction to different metallurgical processes and the importance, Pyrometallurgical, hydrometallurgical and Electrometallurgical processes, Thermodynamics and Kinetic theory, Phase diagrams and its importance in processing, Kinetic Rate Theory and processes in metallurgical smelting operations.

Detailed syllabus:

Introduction to different metallurgical processes and the importance of thermodynamic and kinetic aspects of the processes, Principles involved in pyrometallurgical, hydrometallurgical and electrometallurgical processes, 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. Thermodynamics of Fe-O, C-O, and Fe-C-O systems and their applications to the blast furnace and steelmaking reactions. 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.

Reading:

1. David R Gaskell, Introduction to Metallurgical Thermodynamics, McGraw Hill, 1981.
2. A Volsky, Theory of Metallurgical Processes, Mir Publication, 1971.
3. N Philipova, Theory of Metallurgical Processes, Mir Publication, 1975.
4. J.Z. Szekely, N.J. Themelis, Rate Phenomena in Process Metallurgy, Wiley, 1998.
5. R H Parkar, Introduction to Chemical Metallurgy, 2nd Edition, Pergamon Press, 1978.
6. G H Geiger, D R Poirier, Transport phenomena in Metallurgy, Addison-Wesley, 1973.

MM316	Functional and Biomaterials	DEC	3-0-0	3 Credits

Pre-requisites: PH101-Engineering Physics, CY101-Engineering chemistry, and MM351-Corrosion engineering

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

CO1	Identify materials requirements for bio and functional applications.
CO2	Classify bio and functional materials.
CO3	Apply concepts of bio materials in tissue engineering
CO4	Conduct case studies on materials selection for bio and functional applications

Mapping of course outcomes with program outcomes

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	3	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-
CO2	3	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-
CO3	3	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
CO4	-	-	3	3`	-	-	-	-	-	2	-	3	-	2	1	-

Detailed syllabus

Overview of functional and biomaterials: Historical developments, impact of materials.

Classification of Functional Materials: Dielectrics, piezoelectric materials, sensors, magnetic materials, optoelectronic materials, Semiconductors, shape memory alloys.

Classification biomaterials: Metallic implant materials, ceramic implant materials, polymeric implant materials and composites as biomaterials, Grafts.

Functional materials properties: Electrical, dielectric, piezoelectric, magnetic, optical, semiconductor, shape memory properties.

Cell Structure and properties of biomaterials: Bone structure, Bone properties, Proteins, Bacteria structure, Antibacterial assay, Biocompatibility, Cell-material Interaction: In vivo testing, Cell-material interaction, Cell-signalling, in vitro testing, Cytotoxicity, Clinical trials, Tissue Engineering.

Applications: Case studies on use of functional and biomaterials for various applications.

Reading:

1. Deborah D.L. Chung, Functional Materials: Electrical, Dielectric, Electromagnetic, Optical and Magnetic Applications, World Scientific, 2010.
2. William F. Smith, JavadHashemi, Foundations of Materials Science and Engineering, Mc Graw Hill Education, 2009.
3. J. Park and R.S. Lakes, Biomaterials an introduction, 3rd Edition, Springer, 2007.

4. S. V. Bhat, Biomaterials, 2nd Edition, Narosa Publishing House, 2006.
5. B. Basu, D. Katti and Ashok Kumar, Advanced Biomaterials: Fundamentals, Processing and Applications, John Wiley & Sons, Inc., USA, 2009.
6. Ed. R. D. Ratner, A. S. Hoffman, F. J. Schoen and J. E. Lemons, Biomaterials Science, An Introduction to Materials in Medicine, 2013.

MM351	Corrosion Engineering	DPC	3-1-0	04 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 mechanism of high temperature oxidation.

Mapping of course outcomes with program outcomes

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	3	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
CO2	2	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
CO3	2	2	-	-	2	-	-	-	-	-	-	-	-	2	-	-
CO4	3	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-

Detailed syllabus:

Principles of Corrosion: Introduction, Corrosion rate expressions, Galvanic and Electrochemical Series, Nernst Expression, Electrochemical aspects-Electrochemical reactions, polarization, passivity, Environmental effects- oxygen and oxidizers, velocity, temperature, corrosive concentration, galvanic coupling, Metallurgical aspects.

Forms of Corrosion: ASM Classification, Galvanic corrosion, Crevice corrosion, Pitting, Intergranular corrosion, Selective leaching, Erosion corrosion, Stress corrosion cracking, Hydrogen damage.

Modern Theory-Principles, Free energy, Applications of thermodynamics to corrosion, Pourbaix diagrams, Electrode kinetics, Exchange current density, Activation polarization, Concentration polarization, combined polarization, mixed electrode-potential Theory, Passivity

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

Corrosion rate measurement: Tafel extrapolation, linear polarization

High Temperature Corrosion: Mechanisms and kinetics- Pilling-Bed worth ratio, electrochemical and morphological aspects of oxidation, oxide defect structure, oxidation kinetics, effect of alloying, catastrophic oxidation, internal oxidation.

High temperature materials- mechanical properties, oxidation resistance.

Metal-Gas reactions-decarburization and hydrogen attack, corrosion of metals by sulfur components at high temperatures, hot corrosion of alloys.

Sea/Marine corrosion and Bacterial corrosion: Basic reactions and mechanisms involved.

Specific case studies of corrosion in advanced and critical materials.

Reading:

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	Computational Materials Engineering	PCC	3-0-0	03 credits

Prerequisites: MA201-Mathematics III, CS101-Problem Solving and Computer 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 modelling techniques to solve canonical problems in materials science
CO4	Predict microstructural evolution using phase field method

Mapping of course outcomes with program outcomes:

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	3	3	-	-		-	-	-	-	-	-	-	2	-	-	-
CO2	3	3	-	-	2	-	-	-	-	-	-	-	2	2	-	-
CO3	-	3	2	-	2	-	-	-	-	-	-	-	-	3	-	-
CO4	-	-	3	-	2	-	-	-	-	-	-	-	-	3	-	-

Detailed syllabus:

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

Reading:

1) Michael Heath, Scientific computing: An introductory survey, McGraw Hill, 2002.

2) June Gunn Lee, Computational Materials Science, CRC Press, 2011.

3) K. Ohno, K. Esfarjani and Y. Kawazoe, Computational Materials Science, Springer 1999.

MM353	Materials Characterization	DEC	3 – 0 – 0	03 Credits

Pre-requisites: PH101-Engineering Physics, CY101-Engineering Chemistry, and 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	Demonstrate the Bragg's law of diffraction and the principle of XRD.
CO3	Choose the suitable characterization techniques for microstructural and compositional analysis of materials.
CO4	State the thermal analysis technique and apply them to determine various thermal events in materials.

Mapping of course outcomes with program outcomes

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	3	-	-	-		-	-	-	-	-	-	-	-	-	-	2
CO2	3	3	-	-		-	-	-	-	-	-	-	-	-	-	2
CO3	3	-	-	-	3	-	-	-	-	-	-	-	-	-	-	3
CO4	3	-	-	-	2	-	-	-	-	-	-	-	-	-	-	2

Detailed Syllabus:

Microscopy: Concepts of magnification, Resolution, numerical aperture, depth of field., principles of image formation, DIC illumination, Hot stage microscopy, advantages, limitations .Electron microscopy, SEM and TEM, , Electron beam source, Electron source, sample preparation, Electron specimen interaction, Working principles, lens arrangement, mode of imaging, Bright field image, dark field image, image contrast, SAD. Comparison of OM, SEM and TEM. Advantages, limitations.

X-Ray diffraction, Properties of X-rays X-Ray diffraction methods, Intensities of diffracted beam and structure factor, , Phase mixtures and phase diagram, Determination of crystal structure, Phase identification, stress measurement,.

Surface characterization techniques EDS, WDX, XRF, XPS and AES, and EPMA.

Thermal analysis techniques TGA, DSC, DTA and TMA

Reading:

1. S Zhang, L. Li and Ashok Kumar, Materials Characterization Techniques, CRC Press, 2008.
2. David B. Williams, C.Barry Carter, Transmission Electron Microscopy, A Textbook for Materials Science, 2nd Edition, Springer, 2009.
3. Khangaonkar P R, An Introduction to Material Characterization, Penram Intl. Publishing (India) Pvt. Ltd,mumbai,2010.
4. B.D.Cullity and S.R.Stock, Elements of X-Ray Diffraction, 3rd Edition, Prentice Hall, NJ, 2001.
5. ASM Handbook, Vol.10, Materials Characterization, ASM International, USA, 1998.

MM354	Corrosion Engineering Laboratory	PCC	0-1-2	02 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

Mapping of course outcomes with program outcomes

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	3	-	-	-	3	-	-	-	3	-	-	-	-	-	-	3
CO2	2	-	3	-	1	-	-	-	3	-	-	-	-	-	-	2
CO3	3	3	-	-	3	-	-	-	3	-	-	-	-	-	-	3
CO4	3	3	-	-	3	-	-	-	3	3	-	-	-	-	-	3

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.

Reading:
Corrosion Laboratory manual

MM355	Computational materials engineering laboratory	PCC	0-1-2	02 credits

Prerequisites: None
Course outcomes: At the end of the course students will be able to:

CO 1	Appreciate the importance of modelling and simulation in materials engineering
CO 2	Apply explicit and implicit methods to solve diffusion problems
CO 3	Use atomistic modelling techniques to solve canonical problems in materials science
CO 4	Study microstructural evolution using phase field method

Mapping of course outcomes with program outcomes

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	3	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
CO2	3	-	2	-	2	-	-	-	-	-	-	-	-	2	-	-
CO3	3	-	2	-	2	-	-	-	-	-	-	-	-	2	-	-
CO4	3	-	2	-	2	-	-	-	-	-	-	-	-	2	-	-

List of experiments:

1) Solve transient diffusion equation using explicit finite difference method and Neumann boundary conditions. Compare the output with analytical solution.
2) Solve transient diffusion equation using explicit finite difference method and periodic boundary conditions. Compare the output with analytical solution.
3) Solve transient diffusion equation using implicit finite difference method and periodic boundary conditions. Compare the output with analytical solution.
4) Using LAMMPS measure the density of a gas diffusing in a closed system.
5) Using LAMMPS measure the melting temperature of pure metals.
6) Using Pott’s model to simulate grain growth.
7) Solve 1D Cahn-Hilliard equation to measure interfacial energy and interfacial width.
8) Obtain the critical radius of the precipitate phase for a given amount of supersaturation in binary alloy.
9) Simulate spinodal decomposition by solving 2D Cahn-Hilliard equation.
10) Simulate dendritic growth using Kim-Kim-Suzuki model.

MM356	Materials Characterization Laboratory	PCC	0 – 1 –2	02 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.

Mapping of course outcomes with program outcomes

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	3
CO2	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	3
CO3	-	3	-	-	3	-	-	-	-	-	-	-	-	-	-	3
CO4	-	-	3	-	3	-	-	-	-	-	-	-	-	-	-	3
CO5	-	-	3	-	3	-	-	-	-	-	-	-	-	-	-	3

List of Experiments

1. Image analysis of microstructures using OM.
2. Microstructural analysis using SEM
3. Fractography analysis using SEM
4. Chemical Analysis of phases through SEM-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
8. Demonstration of Atomic Force microscopy, ICP-OES and XRF

Reading:

Materials Characterization Techniques Laboratory Manual

MM361	Introduction to Nano Science and Technology	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

Mapping of course outcomes with program outcomes

PO / CO	PO1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO1 2	PSO 1	PSO2	PSO3	PSO4
CO1	3	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
CO2	3	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
CO3	3	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
CO4	3	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-

Detailed syllabus

Introduction: defining nanotechnology, nanoscale comparison, Challenges of this size scale. Nanoscience vs Nanotechnology.

Classification of Nanomaterials: Challenges of this Size Scale, Application area & opportunity, Classification According to their origin, dimensions & structural configuration; nanocomposite

Size Effect: Structural differences on the nanoscale, Factors Influencing Properties of nanomaterials, Surface Area and Energy, effect of size on optical, electrical, physical & chemical properties

Nanocarbon: Classifications of carbon based nanomaterials; carbon black & its applications; Fullerene: Defination, discovery and structure; Properties- Solubility, Hydrated Fullerene, Superconductivity, Endohedral fullerenes, Existence in the nature, Synthesis (discover) of C60

Carbon Nanotube (CNT): Introduction and defination, discovery, Rolling-up a graphene sheet to form a tube, Chiral Vector; Types of CNTs, Properties of CNTs, Synthesis of CNTs- Laser Ablation method, Synthesis with CO_2 laser, Electric-Arc Method, Solar energy reactor, Chemical vapor Deposition (CVD), Comparison of different synthesis methods

Purification & Sorting of CNTs: The most common impurities, process of purification, Unbundling CNTs, Sorting of Carbon Nanotube, Purity Evaluation

Growth Mechanism of CNT: Tip-growth model & Base-growth model, Grow-in-place Vs. grow-then-place approach; Defects in Carbon nanotubes- Types of defects, Stone-Wales Defects, Role of defects on different properties.

Graphene: Introduction, defining graphene, Graphene Superlatives, Discovery of Graphene, Salient features of the structure, Amazing Mechanical Properties, Electrical Properties, Thermal Conductivity, Optical properties, why graphene is different, Synthesis of Graphene- Top-down approach & Bottom up approach, Mechanical Exfoliation, Hummers Method, Epitaxial Growth, Chemical Vapour Deposition, Electrochemical Exfoliation, Laser Scribing, N-doped Graphene; Applications- Early Applications, Applications in Electrical engineering, Electronics engineering, Mechanical engineering, Biodevices, Energy storage; New Applications-Glass-based electronics, Antibiotics, Ultrasonic Microphones, Lubricant, Mechanical Watch, Solar cells, Camera lenses, NFC Antenna, Super-Silk, Microbots, Water Purification, Sensors; Graphene's future, Challenges Surrounding Graphene

Synthesis of nanomaterials:

Physical Methods- Mechanical Methods, Methods based on Evaporation, Sputter Deposition, Chemical Vapour Deposition, Electric Arc Deposition, Ion Beam Technique, Molicular Beam Epitaxy.

Chemical Methods-synthesis of Metal nanoparticles by colloidal route, Sol-Gel Method, Hydrothermal synthesis, Sonochemical Synthesis, Microwave Synthesis

Nanofluids: Introduction, Characteristic, Methods for Producing Nanoparticles/Nanofluids, Nanofluid Structure, Effect of nanoparticles in NF, Advantages and challenges, Applications

Ferrofluid: Introduction, Synthesis of Magnetite Nanocrystals, Applications

Natural Nanomaterials: Introduction, Biomimicry, lotous effect and its applications, Phenomenon of iridescence in butterflies and its applications, Gecko's Sticky Feet, Shark Skin, Toucan Beaks, Water Striders

Reading:

1. B. S. Murty et al., Textbook of Nanoscience and Nanotechnology, Universities Press (India) Private Limited 2013
2. Sulabha K. Kulkarni, Nanotechnology Principles and Practices, Capital Publishing Company, 2007.
3. H. Hosono, Y. Mishima, H. Takezoe, K.J.D Mackenzie, Nanomaterials- From Research to Applications, Elsevier, 2008.
4. Massimilano Di Ventra, S. Evoy, James R. Heflin Jr, Introduction to Nanoscale Science and Technology, Springer, 2009.
5. Charles P. Poole Jr., Frank J. Owens, Introduction to Nanotechnology, Wiley India, New Delhi, 2010.

MM362	Additive Manufacturing	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 need for Additive Manufacturing (AM) and Rapid Prototyping Technologies
CO2	Describe the principles, process and advantages of different AM systems
CO3	Design and apply AM for customized implants and industrial products
CO4	Identify the fundamentals of Reverse Engineering

Mapping of course outcomes with program outcomes

PO / CO	PO 1	PO2	PO3	PO4	PO5	PO6	PO 7	PO 8	PO9	PO 10	PO 11	PO 12	PSO 1	PSO 2	PSO 3	PSO 4
CO1	3	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-
CO2	3	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-
CO3	3	-	2	-	-	-	-	-	-	-	-	-	2	-	-	-
CO4	-	2	-	-	-	-	-	-	-	-	-	-	-	-	2	-

Detailed syllabus

Introduction: General overview, need of additive manufacturing (AM), reverse engineering (RE), and computer aided design (CAD), computer aided manufacturing (CAM) and AM, AM tooling and uses.

AM Systems: Principle, process, advantages and applications of (i) Stereo lithography (ii)3-D Printing (iii) Fused Deposition Modelling (FDM) (iv) Laminated Object Manufacturing (LOM) (v) Selective Laser Sintering (SLS) (vi) Laser Engineered Net Shaping (LENS) (vii) Direct Metal Deposition (DMD).

Materials and mechanisms: Polymer, photo polymerization and SLS, ceramics for SLS and Laser chemical vapour deposition (LCVD), Metals used in DMD and SLS, effect of rapid solidification and non-equilibrium structure.

Applications: Design and production of Customized implants and prosthesis using AM, Computer Aided Tissue Engineering (CATE).Reactive and Lightweight, Wear and Corrosion resistant and improved thermal properties suitable for Aerospace, Automobile, Oil and Gas and Agriculture.

Reading:

1. C.K Chua., K.F. Leong and C.S. Lim, “Rapid prototyping: Principles and applications”, 3rd Edition, World Scientific Publishers, 2010.

2. A. Gebhardt, “Rapid prototyping”, Hanser Gardener Publications, 2003.
3. L.W. Liou and F.W. Liou, “Rapid Prototyping and Engineering applications: A tool box for prototype development”, CRC Press, 2007.
4. A.K. Kamrani and E.A. Nasr, “Rapid Prototyping: Theory and Practice”, Springer, 2006.
5. P.D. Hilton and P.F. Jacobs, “Rapid Tooling: Technologies and Industrial Applications”, CRC press, 2000.
6. Ian Gibson, David W Rosen, Brent Stucker., “Additive Manufacturing Technologies: Rapid Prototyping to Direct Digital Manufacturing”, Springer, 2010
7. D.T. Pham, S.S. Dimov, Rapid Manufacturing: The Technologies and Applications of Rapid Prototyping and Rapid Tooling, Springer 2001.

MM363	Advanced Iron and Steel Making Technology	DEC	3 – 0 – 0	3 Credits

Pre-requisites: MM253-Iron Making Technology, and MM301-Steel Making Technology
Course Outcomes: At the end of the course, student will be able to:

CO1	Explain the thermal and chemical aspects of blast furnace.
CO2	Assess the blast furnace productivity.
CO3	Select the smelt reduction processes for iron making.
CO4	Identify the secondary steel making processes.

Mapping of course outcomes with program outcomes

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	3	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-
CO2	3	2	2	2	-	-	-	-	-	-	-	-	2	2	-	-
CO3	3	-	2	-	-	-	-	-	-	-	-	-	2	-	-	-
CO4	3	-	-	-`	-	-	-	-	-	-	-	-	2	-	-	-

Detailed syllabus:
Thermodynamics of C-O, Fe-O, C-O-Fe and C-O-Fe-H_2 systems.

Thermal and chemical feature of the blast furnace: Tuyere flame temperature, Thermal and chemical reserve zones, The Rist diagram. Internal and Gas flow in Blast furnace: Aerodynamic features of the granular zone, Gas flow in wet zones.

Blast furnace productivity: Fuel efficiency and Modern Developments, Fundamentals of blast furnace productivity, effect of agglomerated iron oxides on productivity, coke quality for improved productivity and fuel efficiency.

Blast furnace Modeling and control: Process modeling, Steps involved in Mathematical modeling, Important process models, Real –time process simulator. Models for gas-solid reaction kinetics. Models for the blast furnace

Blast furnace reactions and process dynamics

Agglomeration: sintering and pelletization mechanisms; blast furnace aerodynamics; irregularities.

Direct reduction: gas-based and coal based; reactions in Midrex/Hyl processes, rotary kiln processes and operational difficulties.

Smelt reduction: COREX process, Hismelt process, Romelt process, Finex process, Fast melt process, Itmk3 process, Tecnored process. Mini blast furnace.

Secondary steel Making: Injection ladle metallurgy, Physico chemical principles of refining in the ladle by synthetic slags, Turbulence and agitation of the bath in ladle, Vacuum degassing processes, Refining by remelting, Ladle metallurgy.

Continuous Casting of Steel: Recent developments, Quality control in continuous casting, Thin slab casting, thin strip casting.

Transport Processes, dimensional Analysis and Physical Simulation in Steel Making: Flux calculation through turbulent fluid medium, Physical simulation, Design of a cold model experiment to simulate the slag metal reaction in gas stirred ladle.

Ferroalloy Technology: Production of Fe-Mn, Fe-Si, Si-Mn, Ca-Si, Fe-Cr and low carbon and specialty ferroalloys.

Reading:

1. J.C. Peacey, W. G. Davenport, The Iron Blast Furnace: Theory and Practice, Pergamon, 1979.
2. A. Chatterjje, Beyond the Blast Furnace, CRC Press, 1994.
3. Making, Shaping and Treating of Steel, Vol.1, Ironmaking, 11th Edition, AISE Steel Foundation, 1999.
4. A. Ghosh and A. Chatterji, Iron making and Steel making: Theory and Practice, Prentice-Hall (India), 2008.
5. A. K. Chakrabarti, Steel Making, Prentice- Hall (India), 2007.

MM401	Metal Joining	DEC	3 – 0 – 0	03 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.

Mapping of course outcomes with program outcomes

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	3	-	2	-	-	-	-	-	-	-	-	-	2	-	1	1
CO2	3	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
CO3	3	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1
CO4	2	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-

Brief syllabus:

Metal joining: Introduction to metal joining, welding, brazing, soldering. Heat sources, Types of welding, Fusion welding, Solid state welding, heat flow in welding, Chemical Reactions in welding, basic solidification, post-Solidification, phase Transformations, different zones of welding, dissimilar welding, Defects in welding ,Concepts of Residual Stresses, Distortion, Remedies. Inspection of welds, Weldability Tests.

Nondestructive testing: Visual, Liquid Penetrant, Magnetic Particle, Eddy current, Radiography and Ultrasonic testing .

Detailed Syllabus:

Metal joining: Introduction to metal joining, welding, brazing, soldering., Heat sources, Weld joint design, Types of Welding-**Fusion Welding**: Gas welding, Oxyacetylene Welding, Types of flames, process description and application, Arc welding, Arc characteristics, duty cycle, 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, High energy beam welding-Electron Beam Welding ,Laser Beam Welding , **Solid state welding**: Resistance welding, Spot, seam, projection, flash butt welding , Ultrasonic, Explosion and Friction welding, dissimilar welding.

Welding Metallurgy-. Heat flow in welding, Temperature distribution, Peak temperature, cooling rate, Chemical Reactions in Welding, Basic Solidification, Post-Solidification Phase Transformations, microstructures in different zones of welding,

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

Non-destructive testing: Principles, equipment, applications and limitations of Visual Testing, Liquid Penetrant Testing, Magnetic Particle Testing, Eddy current testing, Radiographic Testing, Ultrasonic testing.

Reading:

1. N.K.Srinivasan, Welding Technology, Khanna publishers, 2008.
2. Sindo Kou, Welding metallurgy, John Willey, 2003, 2nd Edition, USA.
3. J.F. Lancaster, Metallurgy of Welding, Abington Publishing, 6th edition, England. 1999.
4. Richard Little, Welding and Welding Technology, McGraw Hill, 1st 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.

MM402	Metal Forming	PCC	3-0-0	03 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

Mapping of course outcomes with program outcomes:

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	3	2	3	-	-	-	-	-	-	-	-	1	-	2	-	-
CO2	3	2	-	-	-	-	-	-	-	-	-		2	-	-	2
CO3	3	-	-	-	-	-	-	-	-	-	-	-	2	2	-	-
CO4	3	-	-	-	-	-	-	-	-	-	-	-	-	2	-	1

Detailed syllabus:

Introduction: 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 & Teresa 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, Hot working, Cold 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, Hot Extrusion, Deformation, Lubrication, and Defects in Extrusion, Analysis of the Extrusion Process, Cold Extrusion and Cold-Forming, 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

Reading:

1. G.E. Dieter, Mechanical Metallurgy, 3rd Edition, McGraw Hill, New York, 2013.
2. C. J. Richardson, Worked Examples in Metal Working, Institute of Metals, London, 1985.
3. ASM Hand Book, Vol. 14: Forming and Forging, ASM International, 2012.
4. Surender Kumar, Principles of Metal Working, 2nd Edition, Oxford & IBH, 2001.

MM403	Nonferrous Extractive Metallurgy	PCC	3-1-0	04 Credits

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

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

CO1	Identify techniques for extraction and refining of nonferrous metals.
CO2	Differentiate pyro-, and hydro-metallurgical techniques.
CO3	Design flow sheets for extraction and refining of metals.
CO4	Assess energy efficiency in extraction of Aluminum.

Mapping of course outcomes with program outcomes

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	3	-	-	-	-	-	-	-	-	-	-	-	2	2	-	-
CO2	3	-	-	-	-	-	-	-	-	-	-	-	2	2	-	-
CO3	3	-	-	-	-	-	-	-	-	-	-	-	2	2	-	-
CO4	3	-	-	-	-	-	-	-	-	-	-	-	2	2	-	-

Detailed syllabus

Copper: Roasting, matte smelting, converting, fire-refining and electro-refining, Ausmelt /Isasmelt process, Hydrometallurgy of copper, recovery of copper from leach liquor.

Aluminium: Bayer process, its chemistry and practice. Hall-Heroult process: carbon anodes, theoretical principles, factors influencing the process, current and energy efficiencies.

Zinc: Pyrometallurgy, sinter-roasting and imperial smelting process. Hydrometallurgical extraction: roasting, leaching and electrowinning.

Lead: Blast furnace smelting, refining of lead bullion.

Titanium: Up-gradation of ilmenite and Kroll process.

Uranium: Acid and alkali processes for digestion of uranium ores. Production of reactor grade uranium and UO_2.

Gold: Cyanidation process. Carbon-in pulp process. Other important metals such as nickel and magnesium, major non-ferrous metal production in India.

Reading:

1. K. Grjortheim and B.J. Welch, Aluminium Smelter Technology- A pure and Applied Approach, Aluminium-Verlag GMBH, 1980.
2. W.G. Davenport, M. J. King, M. E. Schlesinger and A. K. Biswas, Extractive Metallurgy of Copper, Pergamon, 2002.
3. H. S. Ray, R. Sridhar and K.P. Abraham, Extraction of Non-Ferrous Metals, Affiliated
1. East –West, 1985.
4. R. Raghavan, Extractive Metallurgy of Non-Ferrous Metals, Vijay Nicole Imprints Private Limited, 2016
5. A.R. Burkin (ed.), Production of Aluminium and Alumina, Wiley, 1987.
6. A.R. Burkin (ed.), Extractive Metallurgy of Nickel, Wiley, 1987.
7. FathiHabashi, Hand Book of Extractive Metallurgy, vol. 1, 2, 3 and 4, Wiley-VCH Breach, 1997.

MM 404	Metal Processing Laboratory	DPC	0– 1– 2	02 Credits

Prerequisite: None

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

CO1	Perform arc welding process.
CO2	Evaluate microstructure and hardness profile of weldments.
CO3	Inspect metal defects using NDT methods Produce rolled sheet products
CO4	Determine strain hardening exponent from the stress-strain diagram.
CO5	Demonstrate the effect of cold working and annealing on microstructure.
CO6	Practice rolling of copper, brass, plain carbon steel and stainless steel.

Mapping of course outcomes with program outcomes:

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	3	-	1	-	-	-	-	-	1	1	-	-	2	-	1	1
CO2	3	-	-	-	-	-	-	-	1	1	-	-	-	-	-	2
CO3	3	-	-	-	-	-	-	-	1	1	-	-	-	-	-	2
CO4	3	-	-	-	-	-	-	-	1	1	-	-	-	2	-	1
CO5	3	-	-	-	-	-	-	-	1	1	-	-	-	-	-	1
CO6	3	-	-	-	-	-	-	-	1	1	-	-	2	-	-	1

List of Experiments:

1. Demonstration of gas tungsten arc (GTA) welding of a given sample
2. Interpretation of the microstructure and hardness of the given weldment
3. Identification of metal defects using liquid penetrant and magnetic particle testing
4. Determination of minimum bend radii, n and k from tension test
5. Study of mechanical properties and micro-structural change of cold worked metals
6. Annealing of cold worked metal and micro-structural changes
7. Perform rolling of copper, brass, stainless steel and plain carbon steel using laboratory rolling mill
8. Effect of strain rate studies on mechanical properties

MM449	Project Work-Part A	PRC	0 – 0 – 4	2 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

Mapping of course outcomes with program outcomes:

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	3	2	2	2	3	1	1	2	3	3	2	1	1	1	1	1
CO2	3	2	2	2	3	1	1	2	3	3	2	1	1	1	1	1
CO3	3	2	2	2	3	1	1	2	3	3	2	1	1	1	1	1
CO4	3	2	2	2	3	1	1	2	3	3	2	1	1	1	1	1

MM491	Seminar	PCC	0 – 0 – 2	1 Credit

Pre-requisites: None

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

CO1	Identify an advanced topic in metallurgical and materials engineering
CO2	Conduct thorough literature survey
CO3	Prepare comprehensive report
CO4	Present the topic using multimedia and answer the queries

Mapping of course outcomes with program outcomes:

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	3	2	-	1	-	-	-	-	-	-	-	-	-	-	-	-
CO2	-	2	-	1	-	-	-	-	-	-	-	-	-	-	-	-
CO3	-	-	-	1	-	-	-	2	-	3	-	-	-	-	-	1
CO4	-	-	-	1	-	-	-	1	-	3	-	-	-	-	-	-

MM411	Physical Metallurgy of Non-Ferrous Metals and Alloys	DEC	3-0-0	03 Credits

Pre-requisites: MM201-Physical Metallurgy

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

CO1	Explain the importance of non-ferrous metals and alloys from physical metallurgy perspective.
CO2	Analyze the binary phase diagrams of various important engineering alloys.
CO3	Correlate the microstructure, properties, processing and performance of materials.
CO4	Formulate and solve physical metallurgy related engineering problems.

Mapping of course outcomes with program outcomes

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	3	-	-	-	-	-	-	-	-	-	-	-	-	2	-	2
CO2	3	2	-	-	-	-	-	-	-	-	-	-	-	2	-	
CO3	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
CO4	3	2	1	-	-	-	-	-	-	-	-	-	-	2	-	

Detailed syllabus

Aluminium and its alloys: Classification and designation of Aluminum Alloys, Non-heat treatable Wrought Aluminum Alloys, Heat treatable Wrought and Cast Aluminum Alloys, Al-Cu, Al-Si (Modified and unmodified), Al-Li alloys with their phase diagrams, Compositions, heat treatments, properties and applications.

Copper and its alloys: Copper-Zinc and Copper-Tin Phase Diagrams, Brasses and Bronzes Compositions, heat treatments, properties and applications.

Nickel and its alloys: Ni-Cr alloys, Ni-Al alloys, Ni-Cr-Al alloys, Ni-Cr-Al-Ti alloys, Complex Nickel-base alloys: Solid-solution strengthening of Gamma, solid-solution strengthening of gamma prime, amount of gamma prime. Anti-phase boundary energy, Lattice mismatch, Coarsening of gamma prime, Oxidation and corrosion resistance, longtime phase stability, Applications.

Magnesium and its alloys: Classification of Magnesium Alloys, Wrought and Cast Magnesium Alloys with their Phase Diagrams, Compositions, heat treatments, properties and applications.

Titanium and its alloys: Classification of Titanium Alloys, Compositions, heat treatments, properties and applications.

Lead, Zinc and Tin and their alloys: Compositions, heat treatments, properties and applications.

Babbitts (Antifriction alloys): Compositions, heat treatments, properties and applications.

Precious metal & their alloys: Silver, Gold, Platinum, Palladium & their alloys. Iridium, Osmium, Rhodium, Ruthenium & their electrical applications.

Rare metals and their alloys: Characteristics and mechanical properties of these alloys.

Reading:

1. Y Lakhtin, Engineering Physical Metallurgy, CBS Publishers, 1998.
2. Donald S Clark, Wilbur R Varney, Physical Metallurgy for Engineers, 2nd Edition, Van Nostrand Reinhold Company, 1989.
3. Charlie R Books, Heat Treatment- Structure and Properties of Non-ferrous Alloys, ASM,1982.
4. Sidney H Avner, Introduction to Physical Metallurgy, 2nd Edition, McGraw-Hill, 1997.
5. Metals Handbook–Vol.2: Properties and Selection- Non-ferrous alloys and Pure Metals, ASM,2014.
6. I J Polmear, Light Alloys, 5th Edition, Elsevier, 2017.

MM412	X- Ray Diffraction	DEC	3-0-0	3 Credits

Pre-requisites: MM201-Physical metallurgy and MM251-Phase Transformations and Heat Treatment

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

CO1	Explain the principles of X-ray diffraction
CO2	Determine the diffraction conditions for different crystal structures.
CO3	Distinguish filters and counters / detectors
CO4	Calculate the residual stress and macro texture of materials

Mapping of course outcomes with program outcomes

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	3	2	-	-	-	-	-	-	-	-	-	-	-	-	-	2
CO2	3	-	-	-	-	-	-	-	-	-	-	-	-	2	-	2
CO3	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
CO4	3	2	-	-	-	-	-	-	-	-	-	-	-	-	-	2

Detailed syllabus:

Brief introduction to crystallography, Real and reciprocal lattice, Interaction of electron beam with materials, Generation and properties of X-rays - Continuous and characteristics X-rays, absorption, filter, detection of x-rays, Diffraction of X-rays- Bragg's Law, Ewald sphere construction, Diffraction directions and diffraction methods, Intensities of diffracted beams, Scattering by an electron, Scattering by an atom, Scattering by an unit cell, Structure factor calculations and other factors for simple crystal structures, Extinction rules, Diffraction cameras – Laue transmission and back reflection cameras and nature of Laue photographs, Debye-Scherrer cameras for high and low temperature applications, Powder photographs, Focusing cameras, Pin hole cameras, Application of X-ray diffraction - Crystal structure determination, Precise lattice parameter measurements, Phase diagram determination, Chemical analysis by diffraction, Residual stress measurement, Particle size determination, Macrotexture measurements. Indexing of XRD patterns using Xpert-Highscore software.

Reading:

1. B.D. Cullity,"Elements of X-Ray Diffraction",Addision Wesley Publishing Co., Massachusetts, 1968.
2. C. Suryanarayana and M. Grant Norton,"X-ray diffraction-a practical approach"Springer, 1998.

MM413	Nuclear Metallurgy	DEC	3-0-0	03 Credits

Pre-requisites: None

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

CO1	Explain the concepts of nuclear reactor engineering
CO2	Classify reactor components and their materials
CO3	Identify techniques for disposal of radioactive wastes
CO4	Explain processing of nuclear grade materials

Mapping of course outcomes with program outcomes

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	3	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-
CO2	3	-	-	-	-	-	-	-	-	-	-	-	2	2	-	-
CO3	3	-	-	-	-	2	2	1	-	-	-	-	1	-	-	-
CO4	3	-	-	-	-	-	-	-	-	-	-	-	2	-	2	-

Detailed syllabus

Elements of Nuclear Engineering: Elementary concepts of nuclear reactors. Structure of the nucleus, binding energy, fission reactions, neutron cross sections, moderation of neutrons, multiplication factor. Fission reactions.

Nuclear Reactor Components: Reactors and Materials. Classification of nuclear reactors. Materials for nuclear reactors viz., fuels, moderators, control rods, coolants, reflectors and structural materials. Fabrication of fuel and cladding materials.

Radiation: Radiation Effects. Interaction of radiation with materials. Radiation hazards, safety and shielding. Uses of radioactive isotopes.

Nuclear Reactor Waste Disposal: Disposal of radioactive wastes.

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.

Indian Nuclear Power Programme: Indian Reactors and Nuclear Energy Programme in India.

Reading:

1. John R. Lamarsh and Anthony J. Baratta, Introduction to Nuclear Engineering, Prentice Hall, 2001.
2. S. Glasstone and A. Sesonke, Nuclear Reactor Engineering, Van Nostrand, 1994.
3. J. Kenneth Shultis and Richard E. Faw, Fundamentals of Nuclear Science and Engineering, Marcel Dekkar, 2002
4. H. S. Ray, R. Sridhar and K. P. Abraham, Extraction of Non-Ferrous Metals, Affiliated East-West Press, 1985.
5. Geoffrey F. Hewitt and John G. Collier, Introduction to Nuclear Power, Taylor and Francis, 1997.
6. K. Almenas and R .Lee, Nuclear Engineering: An Introduction, Springer Verlag, 1992.
7. TatjanaJevremovic, Nuclear Principles in Engineering, Springer, 2009.
8. Kenneth D. Kok, Nuclear Engineering Hand Book, CRC Press, 2009.

MM414	Refractory and Rare Metal Extraction	DEC	3-0-0	3 Credits

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

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

CO1	Identify ore break down techniques
CO2	Explain concentration techniques for leach solutions
CO3	Design flow sheets for extraction rare and refractory metals.
CO4	Identify high temperature reduction techniques

Mapping of course outcomes with program outcomes:

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	3	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
CO2	3	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-
CO3	3	-	2	-	-	-	-	-	-	-	-	-	1	1	-	-
CO4	3	-	-	-	-	-	-	-	-	-	-	-	2	1	-	-

Detailed syllabus:

Ore Breakdown Techniques: Ore breakdown of different refractory and rare metals by acid and alkali leaching techniques, breakdown by chlorination, fluoride breakdown processes.

Purification Processes: Purification techniques, purification of uranium by solvent extraction and ion exchange, purification of thorium by ion exchange techniques, production by fluidized bed processes, process design, Dryway conversion processes.

Metal Production Techniques: Production of uranium tetra fluoride and thorium fluoride, Metal production by high temperature reduction techniques, metal powder and sponge production techniques, Molten salt electrolytic processes, Electrolysis of beryllium chloride, production of uranium metal by electrolysis, zirconium electrolysis from chloride-fluoride melt, iodide decomposition processes, flow sheets from ore to metal.

Reading:

1. C.A. Hampel, Rare Metals Hand Book, Robert E. Krieger Publishing Company,1971.
2. FathiHabashi, Hand Book of Extractive Metallurgy, Vols. II and III, Wiley- VCH, 1997
3. W. D. Jamrack, Rare Metal Extraction by Chemical Engineering Techniques, Pergamon, 1963.

SM702	Industrial Management	ESC	3 – 0 – 0	3 credits

Prerequisite: None

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

CO1	Explain the four evolutionary phases of the organizational theories their circumstances and the consequences.
CO2	Examine organizational systems with time and motion study, inventory and quality for productivity improvements.
CO3	Understand the marketing management process to discuss marketing mix in formulation of marketing strategies
CO4	Calculate project schedule along with the interdependencies using PERT/CPM techniques.

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-
CO2	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-
CO3	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-
CO4	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-

Detailed Syllabus

Introduction - Overview of organizational theory and theoretical perspectives

Rational and natural systems

The evolution of organizational theory - rational systems and Natural systems
Work study: Productivity and its role in the economy; Techniques for improving productivity; Method study; Principles of motion economy; Stop watch time study; Work sampling
Quality management: Dimensions of quality; Process control charts both attributes and variables. Sampling Plan - LTPD and AOQL concepts. Taguchi's Quality Philosophy; Quality function deployment; Introduction to TQM. QMS and EMS.
Inventory Management: Purpose of inventories; Inventory costs; ABC classification; Economic Order Quantity (EOQ); P and Q systems of inventory control.

Organizational behavior

The individual, The Group, Organization system (structure and culture)

Open systems and behavioral decision-making

Other management topics

Marketing management process; 4P's of marketing mix; Target marketing; Product life cycle and marketing strategies

Project Management: Project activities; Network diagrams; Critical path method (CPM); Programme Evaluation and Review Technique (PERT). Project crashing. Slack computations, Resource leveling

Reading:

1) Robbins, S. P., & Judge, T. A. Organizational behavior.2001.
2) Jones, G. R., & Jones, G. R. (2013). *Organizational theory, design, and change*. Upper Saddle River, NJ: Pearson
3) Taylor, F.W. 1916. Principles of Scientific Management, 30-144
4) Besterfield (2015). Total Quality Management. Pearson Education India; 4 editions
5) Khanna, O. P. (1980). *Industrial engineering and management*. Dhanpat Rai.
6) Kottler, P., & Keller, K. L. (2011). Marketing Management 14^{th} Global Edition.
7) Weber, M. Economy and Society 1978 pp.212-254, 956-975

MM451	Ceramics and Composites	DEC	3 – 0 – 0	03 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 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 and composite materials for a particular application

Mapping of course outcomes with program outcomes:

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	3	-	-	-	-	-	-	-	-	-	-	-	-	-	3	1
CO2	3	-	-	-	-	-	-	-	-	-	-	-	-	-	3	
CO3	3	-	-	-	-	-	-	-	-	-	-	-	-	-	3	1
CO4	3	-	-	-	-	-	-	-	-	-	-	-	-	-	3	1
CO5	3	-	2	-	-	-	-	-	-	-	-	-	-	-	3	

Detailed 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.

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.

Reading:

1. Deborah D. L. Chung , Composite Materials: Science and Applications, Second Edition, Springer, 2009
2. W. David Kingery, H. K. Bowen and Donald R. Uhlmann, Introduction to Ceramics, 2nd Edition, John Wiley & Sons, 2004.
3. F.L. Matthews and R.D. Rawlings, Composite Materials: Engineering and Science, CRC Press, 1999.
4. B. Raymond, Seymour and Charles E. CarraherJr, Polymer Chemistry, An Introduction, 2nd Edition,Marcel Dekkar, Inc. New York, 1987.
5. Krishan Kumar Chawla, Composite Materials- Science and Engineering, Springer, 2012.

MM499	Project Work-Part B	PRC	0 – 0 – 8	4 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

Mapping of course outcomes with program outcomes:

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	3	2	2	2	3	1	1	2	3	3	2	1	1	1	1	1
CO2	3	2	2	2	3	1	1	2	3	3	2	1	1	1	1	1
CO3	3	2	2	2	3	1	1	2	3	3	2	1	1	1	1	1

MM461	**SURFACE ENGINEERING**	**DEC**	**3-0-0**	**03 Credits**

Pre-requisites: MM251-Phase Transformations and Heat Treatments

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 overcome friction and wear, corrosion and oxidation.

Mapping of course outcomes with program outcomes

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	3	1	2	-	-	-	-	-	-	-	-	-	-	2	-	1
CO2	3	-	-	-	-	-	-	-	-	-	-	-	-	2	-	1
CO3	3	-	2	-	2	-	-	-	-	-	-	-	-	-	-	3
CO4	3	-	2	-	-	-	-	-	-	-	-	-	-	-	-	1

Detailed 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.

Introduction to 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), 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.

Process comparisons: Availability, coating thickness, distortion tendency of component, surface roughness and finishing, wear resistance, corrosion resistance, and Cost.

Characterization and Evaluation of coatings. Wear testing and corrosion testing. Designing of surface engineering processes, and some case studies.

Readings:

1. J. R. Davis, Surface Engineering for corrosion and wear resistance, ASM International, 2001
2. K. G. Budinski, Surface Engineering for Wear Resistance, Prentice Hall, New Jersey, 1998.
3. J. R. Davis, Surface hardening of steels-understanding the basics, ASM International, 2002.
4. ASM Metal Hand Book, Vol 5, Surface Engineering, ASM Int., 2004.
5. G.W.Stachowiak& A.W .Batchelor , Engineering Tribology, Butterworth-Heinemann, UK, 2005
6. S.K.Basu, S.N.Sengupta&B.B.Ahuja, Fundamentals of Tribology, Prentice – Hall of India Pvt Ltd, New Delhi, 2005

MM462	Energy Materials	DEC	3-0-0	3 Credits

Pre-requisites: None

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 production and conversion.
CO3	Describe materials for energy storage.
CO4	Suggest materials for specific energy applications.

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	3	-	-	-	-	-	1	-	-	-	-	-	-	-	2	-
CO2	3	-	-	-	-	-	1	-	-	-	-	-	-	-	2	-
CO3	3	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
CO4	3	-	2	2	-	1	-	-	-	-	-	-	-	-	2	-

Detailed Syllabus

Requirement and challenges of energy efficient materials technology. Materials for energy conversion/ production: materials for solar cells, materials for hydrogen generation, fuel cell materials, advances in lead-acid battery components, nuclear materials, light emitting diodes, thermocaloric, electrocaloric and magnetocaloric materials. Materials for energy storage: lithium ion batteries, supercapacitors, hydrogen energy storage, phase change materials. Introduction to smart grid.

Reading:

1. Arno Smelts, Solar Energy: The physics of engineering of photovoltaic conversion, technologies and systems, UIT Cambridge, 2016
2. D. M. Rowe, Materials, Preparation and Characterization in Thermoelectrics, Vols. 1& 2, CRC Press, 2012
3. C Julian and A Mauger, Lithium Batteries, Springer Nature, 2015
4. Robert Huggins, Energy Storage, Springer Nature, 2015
5. T.C. McAuliffe, Hydrogen and Energy, Palgrave Macmillan, 1980

MM463	Pollution and its Control in Metallurgical Industries	DEC	3-0-0	03 Credits

Pre-requisites: None

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

CO1	Explain the sources of pollution from metallurgical industries.
CO2	Quantify pollutants from process industries.
CO3	Propose methods for prevention of pollution.
CO4	Perform case studies on pollution control in Metallurgical Industries.

Mapping of course outcomes with program outcomes

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	2	-	-	-	-	1	2	1	-	-	-	-	1	-	-	-
CO2	2	-	-	-	-	-	2	-	-	-	-	-	1	-	-	-
CO3	2	-	2	-	-	2	2	1	-	-	-	-	1	-	-	-
CO4	2	-	-	-	-	1	2	1	-	-	-	-	1	-	-	-

Detailed syllabus:

Principles of Pollution: Definition, Classification of pollution methods, Qualification techniques to identify pollution, Quantification methods of pollution, Standards and Rules applicable to pollution.

Sources of Pollution: Different kinds of pollutants and their identification techniques,

Pollution control: Established pollution control and measures, Techniques to eradicate/minimize pollution, Prevention of pollution by means of instruments and design.

Pollution in Industries: Iron and Steel industries- causes, identification and control; Smelting industries-causes, identification and control, Sponge iron industries-causes, identification and control, Non-ferrous smelting industries-causes, identification and control, Foundries: causes, identification and control, Rolling Mills: acids/chemicals used during pickling,Cooling lubricants, etc., Welding industries: Fumes, poisonous gases and Slag disposal.

Standards and Regulations of pollution in India.

Reading:

1. R C Gupta, Energy and Environmental management in Metallurgical industries, PHI, 2012.
2. B Mazumdar, M K Mishra, Managing Wastes from Aluminum Smelter Plants, Woodhead Publishers, 2011.
3. S C Bhatia, Pramod Kumar, Sarvesh Devraj, Industrial Pollution and its Control, Woodhead Publishers, 2017.
4. Pasquale Cavaliere, Ironmaking and Steelmaking processes- Greenhouse emissions, control and reduction, Springer, 2016.
5. G L Datta, K B De, A Nag, Foundry Moulding Materials and Pollution, New Age Publishers, 2005.
6. Bhaskar Nath, Georgi Stefanov Cholakov, Pollution Control Technologies, Vol III, EOLSS Publishers, 2009.

MM464	Metallurgical Waste Recycling	DEC	3-0-0	3 Credits

Pre-requisites: MM202-Unit processes in extractive metallurgy, MM253-Iron making, MM301 Steel making technology and MM403-Non-ferrous extractive metallurgy

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.

Mapping of course outcomes with program outcomes

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	2	-	-	-	-	1	2	-	-	-	-	-	1	-	-	-
CO2	2	-	-	-	-	3	3	-	-	-	-	-	1	-	-	-
CO3	2	-	-	-	-	2	2	-	-	-	-	-	1	-	-	-
CO4	2	-	-	-	-	1	2	-	-	-	-	-	1	-	-	-

Detailed 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

Reading:

1. F. Woodard, Industrial waste treatment handbook: Butterworth-Heinemann, 2001
2. H.F. Lund, Recycling Handbook, 2nd Edition, McGraw-Hill, 2000.
3. S. Ramachandra Rao, Resource recovery and recycling from metallurgical wastes, Elsevier, 2006.
4. M. Kutz, Environmentally conscious materials and chemicals processing, John Wiley & Sons, 2007.

MM465	Non-Destructive Testing	DEC	3-0-0	03 Credits

Pre-requisites: PH101-Engineering Physics

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

Mapping of course outcomes with program outcomes

PO / CO	PO 1	PO2	PO3	PO4	PO5	PO6	PO 7	PO 8	PO9	PO 10	PO 11	PO 12	PSO 1	PSO 2	PSO3	PSO 4
CO1	3	1	1	-	2	-	-	-	-	-	-	-	-	-	-	2
CO2	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
CO3	3	2	2	-	2	-	-	-	-	-	-	-	-	-	-	3
CO4	3	-	-	-	2	-	-	-	-	-	-	-	-	-	-	2

Detailed syllabus:

Introduction to NDT: Manufacturing processes, Types Discontinuities associated with manufacturing processes, Defects in Metals and Alloys, Defects in Ceramics, Fracture Mechanics, and Life Cycle Prediction

Visual Examination, Pressure and leak Testing: Methods of visual, pressure and leak testing and underlying these principles

Liquid penetrant inspection: Principles of liquid penetration, Material and instrumental testing in liquid penetrant inspection, Liquid penetrant inspection technique, Safety in conducting liquid penetrant inspection

Magnetic particle inspection: Principles of magnetism, Material and instruments in magnetic particle inspection, Magnetic particle inspection technique, Safety in conducting magnetic particle inspection

Ultrasonic and Eddy Current Testing: Principles of ultrasound, Testing techniques, Calibration Methods, Evaluation of Mechanical defects, Principles Eddy Current testing, Eddy Current Testing techniques, Impedance-plane Diagrams

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

NDT of cast, formed and welded structures: Casting, forming and Welding defects, acceptability Criteria and case studies.

Advanced NDT techniques: Principles and applications of acoustic and thermal imaging techniques

Readings:

1. Baldevraj, Practical Non-destructive Testing, Wood head publishing limited, 2002
2. A.K.Yahya and N. A. Rahman, Elements of Ultrasonic Non-destructive Testing, Univision Press, 2000.
3. J. Kraukramer and H. Kraukramer, Ultrasonic Testing of Materials, 5th Edition, Springer-Verlag, Berlin, 1990
4. D.J. Hagemaier, Fundamentals of eddy current testing. The American Society for Nondestructive Testing, Inc: Columbus OH43228, USA, 1990.

MM466	Metallurgical Failure Analysis	PCC	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 reasons for failure of materials
CO2	Differentiate fracture modes and failure mechanisms
CO3	Determine fracture toughness of materials
CO4	Predict life of materials under mechanical loading
CO5	Examine failure analysis through case studies.

Mapping of course outcomes with program outcomes

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	3	2	-	-	-	-	-	-	-	-	-	-	-	2	-	-
CO2	3	2	-	-	-	-	-	-	-	-	-	-	-	2	-	-
CO3	3	-	-	-	2	-	-	-	-	-	-	-	-	2	-	2
CO4	3	2	2	-	2	-	-	-	-	-	-	-	-	2	-	2
CO5	3	2	-	-	2	-	-	-	-	-	-	-	-	2	-	2

Detailed syllabus:

Aims of failure analysis, Principal factors in the premature failure of metallic components and structures

Stages of 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, scanning electron microscopy.

Tools and techniques in failure analysis.

Types of failures: ductile, brittle, fatigue, creep, corrosion, wear etc., Failure under creep and fatigue, creep fatigue interaction, life estimation under creep and fatigue.

Fracture modes: Shear mode, cleavage mode, other fracture modes, factors affecting the ductile-brittle relationship, stress systems related to fracture of ductile and brittle metals: Pure loading systems-Tension, Torsion, Compression, Bending and Fatigue. Effect of stress concentration, study of fractograph of metallic components.

Determination of fracture type: Ductile and brittle fracture, failure due to Distortion, Fatigue, Creep, Wear, Corrosion, and Erosion. Elevated temperature failure, stress rupture failure and complex failure. Stress corrosion cracking, hydrogen embrittlement, liquid metal embrittlement, chemical analysis, simulated service testing.

Mixed mode and fatigue failures, Failure mechanisms, Embrittlement phenomena, environmental effects, Failures due to faulty heat treatments, Failures in metal forming and welding

Prevention of failures, Case studies in failure analysis, Case histories of component failures

Readings:

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.

MM467	Materials Selection and Design	PCC	3-0-0	03 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	Review the criteria for materials selection
CO2	Describe heat treatment for modifying microstructure and mechanical properties.
CO3	Mention ceramic and polymeric materials.
CO4	Judge materials for structural, functional and bio applications

Mapping of course outcomes with program outcomes

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	3	-	-	-	-	-	-	-	-	-	-	1	-	-	2	-
CO2	3	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
CO3	3	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
CO4	3	-	2	-	-	-	-	-	-	-	-	-	-	-	2	-

Brief Syllabus:

Introduction to materials in design, Evolution of engineering materials, Limitations in properties and applications of various alloys, criteria for selection of materials, Specific design requirements for ferrous and non-ferrous alloys, ceramics and polymers, in varied applications, corrosion resistant, high temperature, low-temperature and cryogenic, wear resistant, magnetic, electrical and electronic applications, pressure vessels and boilers, springs, bearings, tools, medical implants and prostheses applications, Composites, shape memory alloys, metallic glasses.

Detailed Syllabus:

Materials world and 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.

Materials processing: 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 and 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.

Reading:

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

MM468	High Temperature Materials	DEC	3 – 0 – 0	03 Credits

Prerequisite: None

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

CO1	Explain the principles of oxidation of Metals and alloys
CO2	Classify materials for high temperature applications
CO3	Explain mechanisms of creep, thermal fatigue, oxidation and hot corrosion
CO4	Select and design materials for high temperature applications

Mapping of course outcomes with program outcomes

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	3	2	-	-	-	-	-	-	-	-	-	-	-	2	-	1
CO2	3	-	2	-	-	-	-	-	-	-	-	-	-	1	-	1
CO3	3	-	-	-	-	-	-	-	-	-	-	-	1	-	-	3
CO4	3	-	3	-	-	-	-	-	-	-	-	-	1	-	1	-

Detailed syllabus:

Mechanisms of oxidation, Oxidation of pure metals, Oxidation of alloys, High Temperature Oxidation theory, Reactions of metals in mixed environments, Creep, creep curve, various stages of creep, Andrade's analysis, metallurgical factors influencing creep, stress rupture test, structural changes during creep, activation energy for creep, Factors influencing functional life of components at elevated temperatures, effect of stress, temperatures and strain rate, representation of engineering creep data, Prediction of long time properties, Creep-resistant alloy design.

Heat resistance steels, Stainless steels, Super alloys, Titanium alloys, Intermetallics, Ceramics, composites, Refractory metals and alloys. High temperature Polymers. Case studies on power plant materials, boiler materials, turbine materials, steam engine, jet engines and gas turbine materials.

Reading:

1. G.W. Meetham, M.H. Van de Voorde , Materials for High Temperature Engineering Applications, Springer, 2000.
2. Michael E. KassnerMarı´a-Teresa Pe´rez-Prado, Fundamentals of Creep in Metals and Alloys, Elsevier, 2004.
3. R.W. Evans, B Wilshire, Introduction to creep, Institute of Materials, 1993.
4. David young, High Temperature Oxidation and Corrosion of Metals, 2nd Edition, Elsevier Publications, 2016.
5. Roger C. Reed, The Super alloys: Fundamentals and Applications**,** Cambridge university press, 2006.

MM469	Advanced Characterization Techniques	DEC	3-0-0	3 Credits

Pre-requisites: MM353-Materials Characterization.

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

CO1	Describe the advanced microscopic, spectroscopic, diffraction and surface characterization techniques.
CO2	Discuss the equipment, principles, specimen requirements, and operation of advanced characterization tools
CO3	Compare advanced characterization techniques in terms of their capabilities and application
CO4	Suggest suitable characterization techniques for a particular measurement/analysis

Mapping of course outcomes with program outcomes

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	3	-	-	-	2	-	-	-	-	-	-	-	-	-	-	1
CO2	3	-	-	-	2	-	-	-	-	-	-	-	-	-	-	1
CO3	3	-	-	-	2	-	-	-	-	-	-	-	-	-	-	2
CO4	3	-	-	-	2	-	-	-	-	-	-	-	-	-	-	3

Detailed syllabus:

Introduction to the course: Relevance of advanced characterization to materials development, scientific understanding of phenomena in materials technology.

Advanced microscopic techniques: Introduction; Electron-materials interactions; TEM: HR-TEM, STEM, In-situ TEM; SEM-EBSD, in-situ SEM; AFM, STM.

Advanced spectroscopic techniques: Introduction; UV-Visible spectroscopy, infra-red spectroscopy (FTIR), Raman.

Advanced diffraction techniques: Review of basic diffraction theory; Various SAXS techniques and its applications in characterizing material: SAXS, GISAXS. Properties of neutron radiation; neutron sources; Small angle neutron scattering; Examples

Advanced surface characterization techniques: XPS, AES, SIMS - Importance of surface characterization techniques; Physical principles of XPS, Photoelectric effects; Instrumentation, XPS patterns; Spin orbital Splitting; Quantitative analysis, Chemical effect, Chemical shift, XPS imaging; Auger electron generation; Principle, Chemical effect, Quantitative analysis, Depth profiling, Applications; Static and Dynamic Secondary Ion Mass, Common modes of analysis, Depth Profiling, quantitative and Qualitative analysis; Comparison surface analysis techniques.

Reading:

1. Sam Zhang, Lin Li, Ashok Kumar, Materials Characterization Techniques, CRC press, 2008
2. Yang Leng, Materials Characterization: Introduction to Microscopic and Spectroscopic Methods, Wiley, 2009 (ebook)
3. D.B. Williams and C.B.Carter, Transmission Electron Microscopy, Plenum Press, 2004
4. Terry L.Barr, Modern ESCAThe Principles and Practice of X-Ray Photoelectron Spectroscopy, CRC press, 1994
5. Joseph Goldstein, Dale E. Newbury, David C. Joy, and Charles E. Scanning Electron Microscopy and X-ray Microanalysis, Springer Science, 2003.
6. A. K. Tyagi, Mainak Roy, S. K. Kulshreshtha and S. Banerjee, Advanced Techniques for Materials Characterization, Materials Science Foundations (monograph series) Volumes 49 – 51, 2009.
7. C.R. Brundle, C.A. Evens, Jr, S. Wilson (Editors), Encyclopedia of Materials Characterization, Butterworth-Heinmann, Boston, 1992.

MM470	Special steels and Alloys	DEC	3-0-0	03 Credits

Pre-requisites: None

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

CO1	Explain the principles of the alloying and microstructural development in steels.
CO2	Describe the thermal, mechanical and thermo-mechanical treatments of steels.
CO3	Discuss the steels for heat and corrosion resistance applications
CO4	Select special steels for industrial applications.

Mapping of course outcomes with program outcomes

PO / CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	3	-	-	1	-	-	-	-	-	-	-	-	-	2	-	1
CO2	3	-	-	-	-	-	-	-	-	-	-	-	1	2	-	-
CO3	3	-	2	-	-	-	-	-	-	-	-	-	-	2	-	-
CO4	3	-	2	-	-	-	2	-	-	-	-	-	-	1	-	-

Detailed Syllabus:

Introduction to steels, Influence of alloying elements in steel, Fundamental Study on Homogeneity of Solidification Structure of Steel

HSLA Steels: Thermo mechanical processing of HSLA steels, categories and specifications of HSLA steels, microstructural control, influence of alloying elements and applications.

Dual phase steels: Yield Strength of Dual-Phase Steels, Strain Hardening of Dual-Phase Steels, The Ductile Properties of Dual-Phase Steels.

TRIP steels: Introduction, Manufacturing of TRIP Steels, and Phase Transformations during Heat Treatment to Produce TRIP Steels, Microstructure, and Mechanical Properties of TRIP Steels

Maraging steels, Different types of Maraging steels and applications, heat treatment of Maraging steels

Ultrafine-grained steels: Refinement of Austenitic Microstructure and Its Influence on $\gamma \rightarrow \alpha$ Transformation, Deformation Induced Ferrite Transformation, Microstructure Refining and Strengthening of Low- carbon Bainitic Steel, Martensitic Steel, Carbide-free Bainite/Martensite (CFB/M) Duplex Phase Steel. Extra Low Sulfur and Non-metallic Inclusions Control for Ultra-Fine Grain High Strength Steels, Welding of Ultra-Fine Grained Steels

Stainless steels (ferritic, martensitic, austenitic), high nitrogen stainless steels manufacture and applications, sensitization of stainless steels, Heat and oxidation resistant steels

Tool steels: composition, mechanical properties and applications, Special problems in heat treatment of tool steels

Case studies: Special steels for severe mechanical, chemical and thermal working conditions.

Readings:

1. W.C. Leslie, Physical Metallurgy of Steels, Tech Books, 1991.
2. F.B.Pickering, Physical Metallurgy and Design of Steels, Applied Science Publishers, 1978.
3. E. Pereloma and V. E. David, Phase Transformations in Steels Diffusion less Transformations, High Strength Steels, Modelling and Advanced Analytical Techniques Volume 2, Wood head Publishing Series, 2017
4. S. Mahadev and T. Muralidhar ,Welding and Joining of Advanced High Strength Steels (AHSS), Woodhead Publishing Series, 2017

MM471	Smart Materials	DEC	3-0-0	03 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.

Mapping of course outcomes with program outcomes

PO / CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	3	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
CO2	3	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
CO3	3	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
CO4	3	2	-	-	-	-	-	-	-	-	-	-	-	-	2	-

Detailed 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.

Piezoelectricty and Magnetostriction: 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.

Readings:

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

List of open elective courses

III Year II Semester		IV Year I Semester	
DEPARTMENT OF BIO-TECHNOLOGY			
BT390	Green Technology	BT440	Biosensors
DEPARTMENT OF CHEMICAL ENGINEERING			
CH390	Nanotechnology and applications	CH440	Data driven modelling
CH391	Industrial safety management	CH441	Fuel cell technology
CH392	Industrial pollution control	CH442	Design of experiments
CH393	Soft-computing methods	CH443	Carbon capture, sequestration and utilization
DEPARTMENT OF CHEMISTRY			
CY390	Instrumental Methods In Chemical Analysis	CY440	Chemical and Alternate Energy Systems
		CY441	Chemistry of Nanomaterials
DEPARTMENT OF CIVIL ENGINEERING			
CE390	Environmental Impact Analysis	CE440	Building Technology
DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING			
CS390	Object Oriented Programming	CS440	Management Information Systems
DEPARTMENT OF ELECTRICAL ENGINEERING			
EE390	Linear Control Systems	EE440	New Venture Creation
EE391	Soft Computing Techniques	EE441	Principles of Electric Power Conversion
DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING			
EC390	Communication Systems	EC440	Electronic Measurements and Instrumentation
EC391	Microprocessor Systems		
DEPARTMENT OF HUMANITIES AND SOCIAL SCIENCES			
HS390	Soft Skills	HS440	Corporate Communication
DEPARTMENT OF MATHEMATICS			
MA390	Numerical Solution of Differential Equations	MA440	Optimization Techniques
MA391	Fuzzy Mathematics and Applications	MA441	Operations Research
DEPARTMENT OF MECHANICAL ENGINEERING			
ME390	Automotive mechanics	ME440	Alternative sources of energy
ME391	Entrepreneurship development	ME441	Robust design
DEPARTMENT OF METALLURGICAL AND MATERIALS ENGINEERING			
MM390	Fundamentals of Materials Processing Technology	MM440	Metallurgy for Non-Metallurgists
DEPARTMENT OF PHYSICS			
PH390	Medical Instrumentation	PH440	Nanomaterials and Technology
PH391	Advanced Materials	PH441	Biomaterials and Technology
SCHOOL OF MANAGEMENT			

SM390	Marketing Management	SM440	Human Resource Management

BT390	GREEN TECHNOLOGY	OPC	3 – 0 – 0	3 Credits

Pre-requisites: CY101-Engineering Chemistry

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

CO1	Address smart energy, green infrastructure and non-renewable energy challenges
CO2	Build models that simulate sustainable and renewable green technology systems
CO3	Understand history, global, environmental & economic impacts of green technology
CO4	Explore the usage of microorganism for the bioremediation
CO5	Synthesis the nanoparticles by various biological methods
CO6	Apply the green techniques for the production of renewable fuels

Course Articulation Matrix

PO|PSO CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	2	1	-	1	-	1	2	-	-	-	-	-	2	-	1	-
CO2	1	1	-	1	3	2	1	-	-	-	-	-	2	2	-	-
CO3	2	1	-	1	-	1	2	-	-	-	-	-	3	-	3	-
CO4	2	1	-	1	-	1	2	-	-	-	-	-	1	2	3	-
CO5	1	-	-	1	-	2	-	-	-	-	-	-	2	-	-	-
CO6	-	2	-	2	-	-	3	-	-	-	-	-	1	3	3	-

Detailed Syllabus:

Green Technology definition, factors affecting green technologies, co/green technologies for addressing the problems of Water, Energy, Health, Agriculture and Biodiversity- WEHAB (eco-restoration/ phyto-remediation, ecological sanitation, renewable energy technologies, industrial ecology, agro ecology and other appropriate green technologies); design for sustainability reuse, recovery, recycle, raw material substitution, cleaner production, ISO 14000, wealth from waste, case studies.

Clean Technology: Biotechnology and Microbiology of Degradation of coal – Aerobic and Anaerobic pathway of coal degradation, Biogas technology, Microbial and biochemical aspects, Operating parameters for biogas production, kinetics and mechanism - Dry and wet fermentation. Digesters for rural application - High rate digesters for industrial waste water treatment.

Biomass energy: Concept of biomass energy utilization, types of biomass energy, conversion processes, Wind Energy, energy conversion technologies, their principles, equipment and suitability in Indian context; tidal and geothermal energy, Design and operation of Fixed and Fluidized Bed Gasifiers. Biomass as a major source of energy in India: Fuel-wood use in rural households. Consequences for ecosystems. Future energy scenario in rural areas. Utilization of biomass in industrial and semi-industrial settings. Future utilization of biomass in India. Future of landscape management: optimal management.

Nano particles preparation techniques, Greener Nano synthesis: Greener Synthetic Methods for Functionalized Metal Nan particles, Greener Preparations of Semiconductor and Inorganic Oxide Nano particles, green synthesis of Metal nanoparticles, Nanoparticle characterization methods, Green materials: biomaterials, biopolymers, bioplastics, and composites. Nanomaterials for Fuel Cells and Hydrogen; Generation and storage, Nano-structures for efficient solar hydrogen production, Metal Nanoclusters in Hydrogen Storage Applications, Metal Nanoparticles as Electro-catalysts in Fuel Cells, Nanowires as Hydrogen Sensors.

Reading:

1. Ristinen, Robert Kraushaar, Jack J.A Kraushaar, Jack P. Ristinen, Robert A.,Energy and the Environment, 2nd Edition, John Wiley, 2006, ISBN: 9780471172482; Publisher: Wiley, Location: New York, 2006.
2. B. R Wilson & W J Jones, Energy, Ecology and the Environment, Academic PressInc, 2005.
3. Sarkar S, Fuels and combustion, 2nd ed., University Press, 2009.

CH390	NANOTECHNOLOGY AND APPLICATIONS	OPC	3 – 0 – 0	3 Credits

(Not offered to Chemical Engineering Students)

Prerequisites: None

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

CO1	Understand the properties of Nano-materials
CO2	Synthesize nano-particles
CO3	Characterize Nano-materials.
CO4	Scale up the production of Nanoparticles
CO5	Evaluate safety and health related issues of nano-particles

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	3	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-
CO2	3	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-
CO3	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	3
CO4	-	-	-	2	-	-	-	-	-	-	-	-	-	-	3	-
CO5	-	-	-	-	-	2	2	-	-	-	-	-	-	-	-	-

Detailed Syllabus:

Introduction to Nanotechnology: Introduction to nanotechnology and materials, Nanomaterials, Introduction to nano-sizes and properties comparison with the bulk materials, Different shapes and sizes and morphology.

Fabrication of Nanomaterials: Top Down Approach Grinding, Planetory milling and Comparison of particles, Bottom Up Approach, Wet Chemical Synthesis Methods, Microemulsion Approach, Colloidal Nanoparticles Production, Sol Gel Methods, Sonochemical Approach, Microwave and Atomization, Gas phase Production Methods : Chemical Vapour Depositions.

Kinetics at Nanoscale: Nucleation and growth of particles, Issues of Aggregation of Particles, Oswald Ripening, Stearic hindrance, Layers of surface charges, Zeta Potential and pH.

Carbon Nanomaterials: Synthesis of carbon bucky-balls, List of stable carbon allotropes extended, fullerenes, metallofullerenes, solid C_{60}, bucky onions, nanotubes, nanocones

Quantum mechanics: Quantum dots and its Importance, Pauli exclusion principle, Schrödinger's equation, Application of quantum Dots: quantum well, wire, dot, characteristics of quantum dots, Synthesis of quantum dots Semi-conductor quantum dots

Nanomaterials characterization: Fractionation principles of Particle size measurements, Particle size and its distribution, XRD, Zeta potential, Electronic band structure Electron statistics Application: Optical transitions in solids, photonic crystals, Microscopies SEM, TEM, Atomic Forced Microscopy, Scanning and Tunneling Microscopy.

Applications: Self-assembly and molecular manufacturing, Surfactant based system Colloidal system applications, Functional materials Applications, commercial processes of synthesis of nanomaterials.

Nanoinroganic materials of $CaCO_3$ synthesis, Hybrid Waste Water Treatments systems, Electronic Nanodevices,

Nanobiology: Biological synthesis of nanoparticles and applications in drug delivery, Nanocontainers and Responsive Release of active agents, Layer by Layer assembly for nanospheres, Safety and health Issues of nano materials, Environmental Impacts, Case Study for Environmental and Societal Impacts

Reading:

1. KulkarniSulabha K, Nanotechnology: Principles and Practices, Capital Publishing Company, 2007
2. Stuart M. Lindsay, Introduction to Nanoscience, Oxford University Press, 2009.
3. Robert Kelsall, Ian Hamley, Mark Geoghegan, Nanoscale Science and Technology, John Wiley & Sons, 2005.
4. Gabor L. Hornyak, H.F. Tibbals, Joydeep Dutta, John J. Moore Introduction to Nanoscience and Nanotechnology, CRC Press, 2008.
5. Davies, J.H. 'The Physics of Low Dimensional Semiconductors: An Introduction', Cambridge University Press, 1998.

CH391	INDUSTRIAL SAFETY MANAGEMENT	OPC	3 – 0 – 0	3 Credits

(Not offered to Chemical Engineering Students)

Prerequisites: None.

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

CO1	Analyze the effects of release of toxic substances.
CO2	Select the methods of prevention of fires and explosions.
CO3	Understand the methods of hazard identification and prevention.
CO4	Assess the risks using fault tree diagram.

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	PO1 1	PO 12	PSO 1	PSO 2	PSO 3	PSO 4
CO1	-	**3**	-	-	-	-	-	-	-	-	-	-	-	-	-	**2**
CO2	**3**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO3	**3**	-	-	-	-	**2**	-	-	-	-	-	-	-	-	-	-
CO4	-	-	-	-	-	**3**	-	-	-	-	-	-	-	-	-	-
CO5	-	**3**	-	-	-	-	-	-	-	-	-	-	-	-	-	**2**

Detailed syllabus:

Introduction-Safety Programs, Engineering Ethics, Accident and Loss Statistics, Acceptable Risk, Public Perceptions, The Nature of the Accident Process, Inherent Safety.

Industrial Hygiene-Anticipation and Identification, Hygiene Evaluation, Hygiene Control.

Toxic Release and Dispersion Models-Parameters Affecting Dispersion, Neutrally Buoyant Dispersion Models, Dense Gas Dispersion, Toxic Effect Criteria, Effect of Release Momentum and Buoyancy, Release Mitigation.

Fires and Explosions-The Fire Triangle, Distinction between Fires and Explosions, Flammability Characteristics of Liquids and Vapors, Limiting Oxygen Concentration and Inerting, Flammability Diagram

Hazards Identification- Process Hazards Checklists, Hazards Surveys, Hazards and Operability Studies, Safety Reviews.

Risk Assessment- Review of Probability Theory, Event Trees, Fault Trees.

Safety Procedures: Process Safety Hierarchy, Managing Safety, Best Practices, Procedures-Operating, Procedures-Permits, Procedures-Safety Reviews and Accident Investigations.

Reading:

1. D. A. Crowl and J.F. Louvar, Chemical Process Safety (Fundamentals with Applications), Prentice Hall, 2011.
2. R.K. Sinnott, Coulson & Richardson's Chemical Engineering, Elsevier India, Volume 6, 2006.

CH392	INDUSTRIAL POLLUTION CONTROL	OPC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Analyze the effects of pollutants on the environment.
CO2	Distinguish air pollution control methods
CO3	Assess treatment technologies for wastewater
CO4	Identify treatment technologies for solid waste
CO5	Select treatment methodologies for hazardous and E-waste

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	PO11	PO 12	PSO 1	PSO 2	PSO 3	PSO 4
CO1	-	**3**	-	-	-	-	-	-	-	-	-	-	-	-	-	**2**
CO2	**2**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO3	**2**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO4	**2**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO5	-	-	-	-	**3**	-	-	-	-	-	-	-	-	-	-	-

Detailed Syllabus:

Introduction: Biosphere, Hydrological cycle, Nutrient cycle, Consequences of population growth, Pollution of air, Water and soil.

Air pollution sources & effects: Classification and properties of air pollutants, Emission sources, Behavior and fate of air pollutants, Effect of air pollution.

Meteorological aspects of air pollutant dispersion: Temperature lapse rates and stability, Wind velocity and turbulence, Plume behavior, Dispersion of air pollutants, Estimation of plume rise.

Air pollution sampling and measurement: Types of pollutant sampling and measurement, Ambient air sampling, Stack sampling, Analysis of air pollutants.

Air pollution control methods & equipment: Control methods, Source correction methods, Cleaning of gaseous effluents, Particulate emission control, Selection of a particulate collector, Control of gaseous emissions, Design methods for control equipment.Control of specific gaseous pollutants: Control of NOx emissions, Control of hydrocarbons and mobile sources.

Water pollution: Water resources, Origin of wastewater, types of water pollutants and their effects. Waste water sampling, analysis and treatment: Sampling, Methods of analysis, Determination of organic matter, Determination of inorganic substances, Physical characteristics, Bacteriological measurement, Basic processes of water treatment, Primary treatment, Secondary treatment, advanced wastewater treatment, Recovery of materials from process effluents.
Solid waste management: Sources and classification, Public health aspects, Methods of collection, Disposal Methods, Potential methods of disposal.
Hazardous waste management: Definition and sources, Hazardous waste classification, Treatment methods, Disposal methods.
E-waste: Sources, environmental and social issues, management practices

Reading:

1. Rao C.S., Environmental Pollution Control Engineering, Wiley Eastern Limited, India, 1993.
2. Noel de Nevers, Air Pollution and Control Engineering, McGraw Hill, 2000.
3. Glynn Henry J. and Gary W. Heinke, Environmental Science and Engineering, Prentice Hall of India, 2nd Edition, 2004.
4. Rao M.N., Rao H.V.N, Air Pollution, Tata McGraw Hill Publishing Ltd., 1993.
5. De A.K., Environmental Chemistry, Tata McGraw Hill Publishing Ltd., 1999.
6. George Tchobanoglous, Franklin Louis Burton, H. David Stensel, Metcalf & Eddy, Inc., Franklin Burton, waste water engineering: treatment and reuse, McGraw Hill Education; 4th Edition, 2003.
7. E-waste recycling, NPCS Board of consultants and Engineers, Asia pacific business press Inc. 2015

CH393	SOFT-COMPUTING METHODS	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Use neural networks to control the process plants
CO2	Develop fuzzy logic based controllers for different processes
CO3	Combine fuzzy logic with neural networks for plant control
CO4	Design controllers using genetic algorithms

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	PO1 1	PO 12	PSO 1	PSO 2	PSO 3	PSO 4
CO1	-	-	-	-	**3**	-	-	-	-	-	-	-	**1**	-	-	-
CO2	-	-	**3**	-	-	-	-	-	-	-	-	-	**1**	-	-	-
CO3	-	-	**3**	-	-	-	-	-	-	-	-	-	**1**	-	-	-
CO4	-	-	**3**	-	-	-	-	-	-	-	-	-	-	-	-	-

Detailed syllabus

Introduction to Artificial Neural Networks: Basic properties, Neuron Models, Feed forward networks.

Neural Networks Based Control: Representation and identification, modeling the plant, control structures – supervised control, Model reference control, Internal model control, Predictive control: Examples – Inferential estimation of viscosity an chemical process, Auto – turning feedback control.

Introduction to Fuzzy Logic: Fuzzy Controllers, Fuzzy sets and Basic notions – Fuzzy relation calculations – Fuzzy members – Indices of Fuzziness – comparison of Fuzzy quantities – Methods of determination of membership functions.

Fuzzy Logic Based Control: Fuzzy sets in commercial products – basic construction of fuzzy controller – Analysis of static properties of fuzzy controller – Analysis of dynamic properties of fuzzy controller – simulation studies – case studies – fuzzy control for smart cars.

Neuro – Fuzzy and Fuzzy – Neural Controllers: Neuro – fuzzy systems: A unified approximate reasoning approach – Construction of role bases by self-learning: System structure and learning. Introduction to Genetic algorithms.Controller design using genetic algorithms.

Reading:

1. S. N. Sivanandam and S. N. Deepa, Principles of Soft Computing, John Wiley & Sons, 2007.
2. Bose and Liang, Artificial Neural Networks, Tata McGraw Hill, 1996.
3. Huaguang Zhang, Derong Liu, Fuzzy Modeling and Fuzzy Control, Birkhauser Publishers, 2006.
4. Kosco B, Neural Networks and Fuzzy Systems: A Dynamic Approach to Machine Intelligence, Prentice Hall of India, 1992.
5. Lakshmi C. Jain, N. M. Martin, Fusion of Neural Networks, Fuzzy Systems and Genetic Algorithms: Industrial Applications, CRC Press, 1998.
6. MuhammetÜnal, AyçaAk, VedatTopuz, Hasan Erdal, Optimization of PID Controllers using Ant colony and Genetic Algorithms, Springer, 2013.

CY390	Instrumental Methods In Chemical Analysis	OPC	3 – 0 – 0	3 Credits

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

CO1	Understand the concepts of ultraviolet and visible absorption and fluorescence techniques for material characterization.
CO2	Understand the various liquid, gas and size-exclusion chromatographic techniques the automated continuous analysis of environmental, industrial, production-line material
CO3	Understand the concepts of various electroanalytical techniques for characterization of interfaces and traces of surface adsorbed-materials.
CO4	Understands the principles of thermogravimetry and differential thermal analyses (TGA and DTA) for applications into pharmaceuticals, drugs, polymers, minerals, toxins and in Finger Print Analysis
CO5	Identification of suitable analytical technique for characterization of chemical, inorganic and engineering materials

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	PO1 1	PO 12	PSO 1	PSO 2	PSO 3	PSO 4
CO1	**1**	-	-	-	**1**	-	-	-	-	-	-	-	-	-	-	**1**
CO2	**1**	-	-	-	**1**	-	-	-	-	-	-	-	-	-	-	**1**
CO3	**1**	-	-	-	**1**	-	-	-	-	-	-	-	-	-	-	**1**
CO4	**1**	-	-	-	**1**	-	-	-	-	-	-	-	-	-	-	**1**
CO5	**1**	-	-	-	**1**	-	-	-	-	-	-	-	-	-	-	**1**

Detailed Syllabus:
1. UV-Visible Spectrophotometry and Fluorescence
Beer-Lambert's law, limitations, Molecular fluorescence, influencing factors, basic instruments, standardization, quantitative methods, applications.
2. Atomic spectrometry, atomic absorption, X-ray fluorescence methods
Flame atomic emission and absorption, flame emission photometer, flame absorption spectrometer, spectral interferences, quantitative aspects, X-ray fluorescence principle, instrumentation, quantitative analysis.
3. Chromatography methods
Gas chromatography, High performance liquid chromatography, size exclusion chromatography, Principle, Basic instrumentation, terminology, NPC, RPC, Qualitative and Quantitative applications. Capillary Electrophoresis: Principle and application.

4. Thermo analytical methods
Thermogravimetry, Differential thermal analysis, differential scanning calorimetry, Principle, Block diagram, Applications, Quantitative determinations
5. Electroanalytical methods
Coulometric methods, Polarography, Pulse voltammetric methods, Amperometry, Principles, Applications, Electrochemical sensors, Ion selective, Potentiometric and amperometric Sensors, Applications.
6. Spectroscopic methods
Molecular absorption, Woodward rules, applications, Infra-red absorption, functional group analysis, qualitative analysis, 1H- and 13C-NMR spectroscopy, Principle, Basic instrumentation, terminology, Interpretation of data, Quantitative applications
7. Mass spectrometry
Principles, Instrumentation, Ionization techniques, Characterization and applications.

Reading:

1. Instrumental Methods of Chemical Analysis, Gurdeep Chatwal and Sham Anand, HPH, 2009.
2. Instrumental Analysis – Skoog, Holler and Kouch, Thomson, 2007.
3. Vogel: Text book of quantitative chemical analysis, Mendham, Denny, Barnes and Thomas, Pearson edu, 6th Edition, 2007.
4. Organic spectroscopy, William Kemp
5. Instrumental Methods of analysis – Willard, Meritt and Dean, PHI, 2005.

CE390	Environmental Impact Analysis	OPC	3 – 0 – 0	3 Credits

Pre-requisites: None.

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

CO1	Identify the environmental attributes to be considered for the EIA study.
CO2	Formulate objectives of the EIA studies.
CO3	Identify the suitable methodology and prepare Rapid EIA.
CO4	Prepare EIA reports and environmental management plans.
CO5	Plan the methodology to monitor and review the relief and rehabilitation works.

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	**1**	-	-	-	-	-	**2**	-	-	-	-	-	-	-	-	-
CO2	-	**1**	-	-	-	-	**2**	-	-	-	-	-	-	-	-	-
CO3	-	-	-	**1**	-	-	-	-	-	-	-	-	-	-	-	-
CO4	-	-	-	-	-	-	**2**	-	-	-	**1**	-	-	-	-	-
CO5	-	-	-	-	-	**1**	-	-	-	-	-	-	-	-	-	-

Detailed Syllabus:

Introduction: The Need for EIA, Indian Policies Requiring EIA , The EIA Cycle and Procedures, Screening, Scoping, Baseline Data, Impact Prediction, Assessment of Alternatives, Delineation of Mitigation Measure and EIA Report, Public Hearing, Decision Making, Monitoring the Clearance Conditions, Components of EIA, Roles in the EIA Process. Government of India Ministry of Environment and Forest Notification (2000), List of projects requiring Environmental clearance, Application form, Composition of Expert Committee, Ecological sensitive places, International agreements.

Identifying the Key Issues: Key Elements of an Initial Project Description and Scoping, Project Location(s), Land Use Impacts, Consideration of Alternatives, Process selection: Construction Phase, Input Requirements, Wastes and Emissions, Air Emissions, Liquid Effluents, Solid

Wastes, Risks to Environment and Human, Health, Socio-Economic Impacts, Ecological Impacts, Global Environmental Issues.

EIA Methodologies**:** Criteria for the selection of EIA methodology, impact identification, impact measurement, impact interpretation & Evaluation, impact communication, Methods-Adhoc methods, Checklists methods, Matrices methods, Networks methods, Overlays methods, Environmental index using factor analysis, Cost/benefit analysis, Predictive or Simulation methods. Rapid assessment of Pollution sources method, predictive models for impact assessment, Applications for RS and GIS.

Reviewing the EIA Report: Scope, Baseline Conditions, Site and Process alternatives, Public hearing. Construction Stage Impacts, Project Resource Requirements and Related Impacts, Prediction of Environmental Media Quality, Socio-economic Impacts, Ecological Impacts, Occupational Health Impact, Major Hazard/ Risk Assessment, Impact on Transport System,Integrated Impact Assessment.

Review of EMP and Monitoring: Environmental Management Plan, Identification of Significant or Unacceptable Impacts Requiring Mitigation, Mitigation Plans and Relief & Rehabilitation, Stipulating the Conditions, What should be monitored? Monitoring Methods, Who should monitor? Pre-Appraisal and Appraisal.

Case Studies: Preparation of EIA for developmental projects- Factors to be considered in making assessment decisions, Water Resources Project, Pharmaceutical industry, thermal plant, Nuclear fuel complex, Highway project, Sewage treatment plant, Municipal Solid waste processing plant, Tannery industry.

Reading:

1. Jain, R.K., Urban, L.V., Stracy, G.S., *Environmental Impact Analysis*, Van Nostrand Reinhold Co., New York, 1991.
2. Barthwal, R. R., *Environmental Impact Assessment*, New Age International Publishers, 2002
3. Rau, J.G. and Wooten, D.C., *Environmental Impact Assessment,* McGraw Hill Pub. Co., New York, 1996.
4. Anjaneyulu.Y. and Manickam. V., Environmental Imapact Assessment Methodologies, B.S. Publications, Hyderabad, 2007.
5. Wathern.P. Environmental Impact Assessment- Theory and Practice, Routledge Publishers, London, 2004.

CS390	Object Oriented Programming	OPC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Understand fundamental concepts in object oriented approach.
CO2	Analyze design issues in developing OOP applications.
CO3	Write computer programs to solve real world problems in Java.
CO4	Analyze source code API documentations.
CO5	Create GUI based applications.

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO2	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO3	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO4	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO5	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-

Detailed Syllabus:

Object- oriented thinking, History of object-oriented programming, overview of java, Object-oriented design, Structure of java program. Types and modifiers, Classes, declaring objects in classes, Methods, constructors, garbage collection, Method overloading, passing objects as parameters, Inheritance, various forms and types of inheritance, Multilevel hierarchy, use of super, method overriding, Applications of method overriding, abstract classes, Packages with examples

Interfaces and implementation, Exception handling, types, throwing, creating own exceptions, Multithreading and concepts, its usage and examples, Input/output streams, String operations and examples, Collection classes-array, stack collection, bitset collection, Utility classes-string tokenizer, bitset, date, Applets- methods, creation, designing and examples, Event handling-event classes, Event listener interfaces, AWT classes, working with frames, AWT controls-layout manager, user interface components, Graphics programming

Reading:

1. Timothy Budd, “Understanding object-oriented programming with Java”, Pearson,
2. Herbert Schildt, “ The complete reference Java 2”, TMH,

EE390	LINEAR CONTROL SYSTEMS	OPC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Analyze electromechanical systems using mathematical modelling
CO2	Determine Transient and Steady State behavior of systems using standard test signals
CO3	Analyze linear systems for steady state errors, absolute stability and relative stability
CO4	Design a stable control system satisfying requirements of stability and reduced steady state error

Course Articulation Matrix

CO \ PO	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	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
CO2	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO3	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO4	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Detailed syllabus:

Introduction: Control system, types, feedback and its effects-linearization
Mathematical Modeling of Physical Systems: Block diagram Concept and use of Transfer function. Signal Flow Graphs, Mason's gain formula.
Time Domain Analysis of Control Systems - BIBO stability, absolute stability, Routh-Hurwitz Criterion.
P, PI and PID controllers. Root Locus Techniques - Root loci theory, Application to system stability studies.
Introduction to state variables technique, Analysis of R-L , R-L-C networks.
Frequency Domain Analysis of Control Systems - polar plots, Nyquist stability criterion, Bode plots, application of Bode plots.

Reading:

1. B.C.Kuo, Automatic Control Systems, 7th Edition, Prentice Hall of India, 2009.
2. I.J. Nagarath and M. Gopal: Control Systems Engineering, 2nd Edition, New Age Pub. Co.2008.

EE391	SOFT COMPUTING TECHNIQUES	OPC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Understand the concepts of population based optimization techniques
CO2	Examine the importance of exploration and exploitation in heuristic optimization techniques to attain near-global optimal solution
CO3	Evaluate the importance of parameters in heuristic optimization techniques
CO4	Apply for the solution of multi-objective optimization

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
CO2	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
CO3	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
CO4	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-

Detailed syllabus:

Fundamentals Of Soft Computing Techniques: Definition-Classification of optimization problems- Unconstrained and Constrained optimization Optimality conditions- Introduction to intelligent systems- Soft computing techniques- Classification of meta-heuristic techniques - Single solution based and population based algorithms – Exploitation and exploration in population based algorithms - Properties of Swarm intelligent Systems - Application domain - Discrete and continuous problems - Single objective and multi-objective problems.

Genetic Algorithm And Particle Swarm Optimization: Genetic algorithms- Genetic Algorithm versus Conventional Optimization Techniques - Genetic representations and selection mechanisms; Genetic operators- different types of crossover and mutation operators -Bird flocking and Fish Schooling – anatomy of a particle- equations based on velocity and positions - PSO topologies - control parameters. Application to SINX maximization problem.

Ant Colony Optimization And Artificial Bee Colony Algorithms: Biological ant colony system - Artificial ants and assumptions - Stigmergic communications - Pheromone updating- local-global

- Pheromone evaporation - ant colony system- ACO models-Touring ant colony system-max min ant system - Concept of elistic ants-Task partitioning in honey bees - Balancing foragers and receivers - Artificial bee colony (ABC) algorithms-binary ABC algorithms.

Shuffled Frog-Leaping Algorithm and Bat Optimization Algorithm: Bat Algorithm- Echolocation of bats- Behavior of microbats- Acoustics of Echolocation- Movement of Virtual Bats- Loudness and Pulse Emission- Shuffled frog algorithm-virtual population of frogs-comparison of memes and genes -memeplex formation- memeplexupdation.

Application to multi-modal function optimization

Introduction to Multi- Objective optimization-Concept of Pareto optimality.

Reading:

1. Xin-She Yang, “Recent Advances in Swarm Intelligence and Evolutionary Computation”, Springer International Publishing, Switzerland, 2015.
2. Kalyanmoy Deb “Multi-Objective Optimization using Evolutionary Algorithms”, John Wiley & Sons, 2001.
3. James Kennedy and Russel E Eberheart, “Swarm Intelligence”, The Morgan Kaufmann Series in Evolutionary Computation, 2001.
4. Eric Bonabeau, Marco Dorigo and Guy Theraulaz, “Swarm Intelligence-From natural to Artificial Systems”, Oxford university Press, 1999.
5. David Goldberg, “Genetic Algorithms in Search, Optimization and Machine Learning”, Pearson Education, 2007.
6. Konstantinos E. Parsopoulos and Michael N. Vrahatis, “Particle Swarm Optimization and Intelligence: Advances and Applications”, Information science reference, IGI Global, 2010.
7. N P Padhy, “Artificial Intelligence and Intelligent Systems”, Oxford University Press, 2005.

EC390	Communication Systems	OPC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Understand different modulation and demodulation schemes for analog communications.
CO2	Design analog communication systems to meet desired application requirements
CO3	Evaluate fundamental communication system parameters, such as bandwidth, power, signal to quantization noise ratio etc.
CO4	Elucidate design tradeoffs and performance of communications systems.

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO2	-	-	1		-	-	-	-	-	-	-	-	-	-	-	-
CO3	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
CO4	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-

Detailed syllabus

Signal Analysis**:** Communication Process, Sources of Information, Communication Channels, Modulation Process, Types of Communication, Random Process, Gaussian Process, Correlation Function, Power Spectral Density, Transmission of Random Process through an LTI Filter.

Noise Analysis: External Noise, Internal Noise, White Noise, Narrow Band Noise, Representation of Narrow Band noise In phase and Quadrature Components, Noise Figure, Noise Bandwidth, Noise Temperature.

Amplitude (Linear) Modulation: Linear Modulation Schemes, Generation of AM, Envelope Detector, DSB-SC Product Modulator, Switching Modulator, Ring Modulator, Coherent Detection, Costas receiver, SSB Signal Representation, Filtering Method, Phase Shift Method, Coherent Demodulation, VSB Modulator and Demodulator, Carrier Acquisition using Squaring Loop and Costas Loop, Receiver Model, SNR, Noise in SSB and DSB receivers using coherent detection, Noise in AM Receiver using Envelope detection, Threshold Effect.

Angle (Exponential) Modulation: Types of Angle Modulation, Relation between FM and PM, Narrow Band FM, Wideband FM, Transmission Bandwidth of FM Signals, Generation of FM using Direct and Indirect methods, FM Demodulation using Slope Circuit, Frequency Discriminator, Interference in Angle Modulation, Noise in FM Receiver, FM Threshold Effect, Pre-emphasis and De-emphasis in FM, Model of PLL for FM Demodulation.

Pulse Modulation: Sampling Process, PAM, PWM, PPM, Quantization, PCM, TDM, Digital Multiplexer Hierarchy, DM, DSM, Linear Prediction, DPCM, ADPCM, Noise in PCM System, Companding, Comparison of the Noise Performance of AM,FM,PCM and DM.

Information Theory: Uncertainty, Information, Entropy, Source Coding Theorem, Data Compaction, Mutual information, Channel Capacity, BSC Channel, Information Capacity Theorem, Bandwidth - Power Tradeoff, Huffman Coding.

Reading:

1. S. Haykin, Communication Systems, 4th Editin, John Wiley & Sons, Singapore, 2001.
2. B.P. Lathi, Modern Digital & Analog Communication Systems, 3rd Edition, Oxford University Press, Chennai, 1998.
3. Leon W.Couch II., Digital and Analog Communication Systems, 6th Editin, Pearson Education inc., New Delhi, 2001.
4. A Bruce Carlson, PB Crilly, JC Rutledge, Communication Systems – 4th Edition, MGH, New York, 2002.

EC391	Microprocessor Systems	OPC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Develop basic understanding of microprocessor architecture.
CO2	Design Microprocessor and Microcontroller based systems.
CO3	Understand C, C++ and assembly language programming
CO4	Understand concept of interfacing of peripheral devices and their applications

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO2	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
CO3	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
CO4	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-

Detailed syllabus

Microcomputer Organization: CPU, Memory, I/O, Operating System, Multiprogramming, Multithreading, MS Windows

80386 Micro Processors : Review of 8086,salient features of 80386,Architecture and Signal Description of 80386,Register Organization of 80386,Addressing Modes,80386 Memory management, Protected mode, Segmentation, Paging, Virtual 8086 Mode, Enhanced Instruction set of 80386, the Co- Processor 80387

Pentium & Pentium-pro Microprocessor: Salient features of Pentium microprocessor, Pentium architecture, Special Pentium registers, Instruction Translation look aside buffer and branch Prediction, Rapid Execution module, Memory management, hyper-threading technology, Extended Instruction set in advanced Pentium Processors

Microcontrollers: Overview of micro controllers-8051 family microcontrollers, 80196 microcontrollers family architecture, instruction set, pin out, memory interfacing.

ARM Processor Fundamentals: Registers, current Program Status Registers, Pipeline Exceptions, Interrupts and Vector Table, Architecture Revisions, ARM Processor families, ARM instruction set, Thumb Instruction set-Exceptions Handing, Interrupts, Interrupt Handling schemes, firmware, Embedded operating systems, Caches-cache architecture, Cache policy, Introduction to DSP on the ARM, DSP on the ARM7TDMI,ARM9TDMI.

Case study-Industry Application of Microcontrollers

Reading:

1. Barry B.Brey: Intel Microprocessor Architecture, Programming and Interfacing-8086/8088, 80186, 80286, 80386 and 80486, PHI, 1995.
2. Muhammad Ali Mazidi and Mazidi: The 8051 Microcontrollers and Embedded systems, PHI, 2008
3. Intel and ARM Data Books on Microcontrollers.

HS390	Soft Skills	OPC	3 – 0 – 0	3 Credits

Pre-requisites: None.

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

CO1	Understand corporate communication culture
CO2	Prepare business reports and proposals expected of a corporate professional
CO3	Employ appropriate speech in formal business situations
CO4	Exhibit corporate social responsibility and ethics
CO5	Acquire corporate email, mobile and telephone etiquette

Mapping of course outcomes with program outcomes

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	2	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-
CO2	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-
CO3	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-
CO4	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-
CO5	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-

Detailed Syllabus:

English Language Enhancement: Verbs and tenses, Phrasal verbs, Synonyms, Antonyms, Homonyms - Descriptive Words, Combining Sentences, Business Idioms, Indianisms in English.

Art of Communication, Communication process- Non-verbal Communication- Effective Listening.

Interpersonal and Intra Personal Communication Skills- Self-Awareness- Self-Esteem and Confidence- Assertiveness and Confidence- Dealing with Emotions-Team Concept- Elements of Teamwork- Stages of Team Formation- Effective Team-Team Player Styles-Leadership.

Campus to Company- Dressing and Grooming- The Corporate Fit- Business Etiquette- Communication; media etiquette- Group Discussions, Interviews, and Presentation Skills.

Interview handling skills- Effective Resume-- Common Interview Mistakes- Body-language- Content Aid, Visual Aids- Entrepreneurial Skills Development.

Reading:

1. Robert M. Sherfield, Developing Soft Skills, Montgomery and Moody Fourth Edition, Pearson, 2009.
2. K.Alex, Soft Skills: Know Yourself & Know The world, S. Chand; 2009.
3. Robert Bramson, Coping with Difficult People, Dell, 2009

MA390	NUMERICAL SOLUTION OF DIFFERENTIAL EQUATIONS	OPC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Solve nonlinear differential equations by numerical methods.
CO2	Determine the convergence region for a finite difference method.
CO3	Solve elliptic PDE by finite difference method
CO4	Solve a parabolic PDE by finite difference method
CO5	Solve a hyperbolic PDE by finite difference method

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	**2**	**1**	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO2	**2**	**1**	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO3	**2**	**1**	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO4	**2**	**1**	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO5	**2**	**1**	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Detailed Syllabus:

Ordinary Differential Equations: Multistep (explicit and implicit) methods for initial value problems, Stability and Convergence analysis, Linear and nonlinear boundary value problems, Quasi-linearization, Shooting methods

Finite difference methods: Finite difference approximations for derivatives, boundary value problems with explicit boundary conditions, implicit boundary conditions, error analysis, stability analysis, convergence analysis.

Partial Differential Equations: Classification of partial differential equations, finite difference approximations for partial derivatives and finite difference schemes for Parabolic equations, Schmidt's two level, multilevel explicit methods, Crank-Nicolson's two level, multilevel implicit methods, Dirichlet's problem, Neumann problem, mixed boundary value problem, stability analysis.

Hyperbolic Equations: Explicit methods, implicit methods, one space dimension, two space dimensions, ADI methods.

Elliptic equations: Laplace equation, Poisson equation, iterative schemes, Dirichlet's problem, Neumann problem, mixed boundary value problem, ADI methods.

Reading:

1. M.K. Jain, Numerical Solution of Differential Equations, Wiley Eastern, 1984.
2. G.D. Smith, Numerical Solution of Partial Differential Equations, Oxford Univ. Press, 2004.
3. M.K.Jain, S.R.K. Iyengar and R.K. Jain, Computational Methods for Partial Differential Equations, Wiley Eastern, 2005.

MA391	FUZZY MATHEMATICS AND APPLICATIONS	OPC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Apply operations on Fuzzy sets
CO2	Solve problems related to Propositional Logic.
CO3	Apply Fuzzy relations to cylindric extensions.
CO4	Apply logic of Boolean Algebra to switching circuits.
CO5	Develop Fuzzy logic controllers

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
CO2	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
CO3	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
CO4	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
CO5	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-

Detailed Syllabus:

Crisp set theory (CST): Introduction, Relations between sets, Operations on sets, Characteristic functions, Cartesian products of crisp sets, crisp relations on sets.

Fuzzy set theory (FST): Introduction, concept of fuzzy set (FS), Relation between FS, operations on FS, properties of standard operations, certain numbers associated with a FS, certain crisp sets associated with FS, Certain FS associated with given FS, Extension principle.

Propositional Logic (PL1): Introduction, Syntax of PL1, Semantics of PL1, certain properties satisfied by connectives, inference rules, Derivation, Resolution.

Predicate Logic (PL2): Introduction, Syntax of PL2, Semantics of PL2, certain properties satisfied by connectives and quantifiers, inference rules, Derivation, Resolution

-cuts of FR, Composition of FR, Projections of FR, Cylindric extensions, Cylindric closure, FR on a domain.

Fuzzy Logic (FL): Introduction, Three-valued logics, N-valued logics and infinite valued logics, Fuzzy logics, Fuzzy propositions and their interpretations in terms of fuzzy sets, Fuzzy rules and their interpretations in terms of FR, fuzzy inference, More on fuzzy inference, Generalizations of FL.

Switching functions (SF) and Switching circuits (SC): Introduction, SF, Disjunctive normal form, SC, Relation between SF and SC, Equivalence and simplification of circuits, Introduction of Boolean Algebra BA, Identification, Complete Disjunctive normal form.

Applications: Introduction to fuzzy logic controller (FLC), Fuzzy expert systems, classical control theory versus fuzzy control, examples, working of FLC through examples, Details of FLC, Mathematical formulation of FLC, Introduction of fuzzy methods in decision making.

Reading:

1. M. Ganesh, Introduction to Fuzzy Sets and Fuzzy Logic, PHI, 2001.
2. G.J. Klir and B.Yuan, Fuzzy sets and Fuzzy Logic–Theory and Applications, PHI, 1997.
3. T. J. Ross, Fuzzy Logic with Engineering Applications, McGraw-Hill, 1995.

ME390	AUTOMOTIVE MECHANICS	OPC	3 – 0 – 0	3 Credits

Pre-requisites: None.

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

CO1	Analyze operation and performance indicators of transmission systems, internal combustion engines and after treatment devices.
CO2	Understand operation of engine cooling system, lubrication system, electrical system and ignition system.
CO3	Understand fuel supply systems in an diesel and petrol vehicles
CO4	Analyze current and projected future environmental legislation and its impact on design, operation and performance of automotive power train systems.
CO5	Understand operation and performance of suspension, steering and braking system.
CO6	Understand layout of automotive electrical system and importance of electronic

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	**3**	**3**	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO2	**3**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO3	**3**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO4	-	**3**	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO5	**3**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO6	**1**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Detailed syllabus

Introduction: Layout of an automotive chassis, engine classification.

Cooling Systems: Air cooling, air cleaners, Water cooling: Thermo syphon and pump circulation systems, Components of water cooling systems- Radiator, thermostat etc.

Engine Lubrication: Petroils system, Splash system, Pressure lubrication and dry sump system

Ignition System: Battery, Magneto and Electronic, Engine Starting drives

Fuel supply system: Components in fuel supply system, types of feed pumps, air cleaners, fuel and oil filters, pressure and dry sump systems.

Engine testing and Performance: Performance parameters, constant and variable speed test, heat balance test, performance characteristics. Engine Emissions: SI and CI engine emissions, emission control methods

Automotive electrical and electronics: Electrical layout of an automobile, ECU, sensors, windscreen wiper, Electric horn.

Transmission: Clutch- Single and multiplate clutch, semi & centrifugal clutch and fluid flywheel, Gear box: Sliding mesh, constant mesh and synchromesh gear box, selector mechanism, over drive, Propeller shaft and Differential.

Suspension System: Front and rear suspension, shock absorbers, Rear Axles mountings, Front Axle. Steering Mechanism: Manual and power steering systems, Braking System: Mechanical, Hydraulic and Air braking systems.

Engine service: Engine service procedure.

Reading:

1. S. Srinivasan, Automotive Mechanics, Tata McGraw-Hill, 2004.
2. K.M.Gupta, Automobile Engineering, Vol.1 and Vol.2, Umesh Publications,2002
3. Kirpal Singh, Automobile Engineering, Vol.1 and Vol.2, Standard Publishers, 2003.
4. William H.Crouse and Donald L. Anglin, Automotive Mechanics, Tata McGraw-Hill, 2004
5. Joseph Heitner, Automotive Mechanics, East-West Press, 2000.

ME391	ENTREPRENEURSHIP DEVELOPMENT	OPC	3 – 0 – 0	3 Credits

Pre-requisites: None.

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

CO1	Understand entrepreneurship and entrepreneurial process and its significance in economic development.
CO2	Developanideaofthesupportstructureandpromotionalagenciesassistingethical entrepreneurship.
CO3	Identify entrepreneurial opportunities, support and resource requirements to launch a new venture within legal and formal frame work.
CO4	Develop a framework for technical, economic and financial feasibility.
CO5	Evaluate an opportunity and prepare a written business plan to communicate business ideas effectively.
CO6	Understand the stages of establishment, growth, barriers, and causes of sickness in industry to initiate appropriate strategies for operation, stabilization and growth.

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	-	-	-	-	-	-	-	-	-	**1**	-	-	-	-	-	-
CO2	-	-	-	-	-	-	-	**2**	-	-	-	-	-	-	-	-
CO3	-	-	-	-	-	-	-	**2**	-	-	-	-	-	-	-	-
CO4	**2**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO5	-	-	-	-	-	-	**1**	-	-	-	-	-	-	-	-	-
CO6	-	-	-	-	-	-	-	-	**1**	-	-	-	-	-	-	-

Detailed syllabus

Entrepreneur and Entrepreneurship: Introduction; Entrepreneur and Entrepreneurship; Role of entrepreneurship in economic development; Entrepreneurial competencies and motivation; Institutional Interface for Small Scale Industry/Enterprises.

Establishing Small Scale Enterprise: Opportunity Scanning and Identification; Creativity and product development process; Market survey and assessment; choice of technology and selection of site.

Planning a Small Scale Enterprsies**:** Financing new/small enterprises; Techno Economic Feasibility Assessment; Preparation of Business Plan; Forms of business organization/ownership.

Operational Issues in SSE**:** Financial management issues; Operational/project management issues in SSE; Marketing management issues in SSE; Relevant business and safet Laws.

Performance appraisal and growth strategies**:** Management performance assessment and control; Causes of Sickness in SSI, Strategies for Stabilization and Growth.

Reading:

1. G.G. Meredith, R.E.Nelson and P.A. Neek, The Practice of Entrepreneurship, ILO, 1982.
2. Dr. Vasant Desai, Management of Small Scale Enterprises, Himalaya Publishing House, 2004.
3. A Handbook for New Entrepreneurs, Entrepreneurship Development Institute of India, Ahmedabad, 1988.
4. Bruce R Barringer and R Duane Ireland, Entrepreneurship: Successfully Launching New Ventures, 3rd Edition, Pearson, 2013.

MM390	Fundamentals of Materials Processing Technology	OPC	3 – 0 –0	03 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 engineering materials.
CO2	Appreciate material processing techniques.
CO3	Select material processing technique for a given material and application.
CO4	Explain surface engineering techniques and their engineering significance.

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Detailed syllabus

Introduction to engineering materials: Metals, alloys and phase diagrams, ferrous metals, non-ferrous metals, super alloys, guide to processing of metals; **ceramics**-structure and properties of ceramics, traditional ceramics, new ceramics, glass, some important elements related to ceramics; **polymers**-fundamentals of polymer science and technology, thermoplastic and thermosetting polymers, elastomers; **composite materials**-classification of composite materials, metal matrix, polymer matrix and ceramic matrix composites.

Fundamental properties of materials: mechanical properties-stress-strain relationships, hardness, tensile properties, effect of temperature on properties, visco-elastic behaviour of polymers, thermal properties and electrical properties of metals, polymers, ceramics and composites.

Metal casting fundamentals and metal casting processes: Overview of casting technology, melting and pouring, solidification and casting, sand casting, other expendable-mold casting processes, permanent-mold casting processes, casting quality, metals for casting.

Particulate processing of metals and ceramics: Powder metallurgy-characterization of engineering powders, production of metallic powders, conventional processing and sintering, alternative processing and sintering techniques, materials and products for powder metallurgy, design considerations in powder metallurgy, processing of traditional ceramics, processing of new ceramics, cermet's and their processing.

Fundamentals of metal forming and shaping processes, such as rolling, forging, extrusion, drawing, sheet metal forming: Overview of metal forming, friction and lubrication in metal forming; bulk deformation processes in metal forming-**rolling**, other deformation processes related to rolling, **forging**, other deformation processes related to forging, **extrusion**, wire and bar drawing; cutting and bending operations, **sheet-metal drawing**, other sheet metal forming operations, dies and presses for sheet-metal processes, sheet-metal operations not performed in presses.

Fundamentals of welding: Overview of welding technology, the weld joint, physics of welding, features of a fusion-welded joint; Welding processes-arc welding, resistance welding, oxy-fuel gas welding, other fusion welding processes, solid-state welding, weld quality, weldability; brazing, soldering and adhesive bonding.

Surface engineering: Importance of surface engineering, classification of surface engineering processes, introduction to thermal, mechanical, thermo-chemical and electro-chemical surface engineering processes with their advantages, limitations and applications.

Reading:

1. Kalpakjian and Schmid, Manufacturing Engineering and Technology, Prentice Hall, New Jersey, 2013.
2. Mikell P. Groover, Fundamentals of Modern Manufacturing, John Wiley & Sons, Inc, New Jersey, 2010.
3. DeGarmo, Black, and Kohser, Materials and Processes in Manufacturing, John Wiley & Sons, Inc, New York, 2011.
4. R. S. Parmar, Welding processes and Technology, Khanna Publishers, 2010
5. H.S.Bawa, Manufacturing Technology-I, Tata Mc Graw Hill Publishers New Delhi, 2007.
6. Serope Kalpakjian, Manufacturing processes for Engineering Materials, Addison Wesley, 2001.

PH390	Medical Instrumentation	OPC	3 – 0 – 0	3 Credits

Pre-requisites: None.

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

CO1	Understand the origin of bio-potentials and their physical significance.
CO2	Understand anatomy and functioning of human heart and its common problems.
CO3	Analyze ECG, ENG and EMG signals and instrumentation.
CO4	Compare different techniques of measuring blood pressure, blood flow and volume.
CO5	Interpret the principle and operation of therapeutic and prosthetic devices.
CO6	Differentiate between the various techniques for measurement of parameters.

Mapping of course outcomes with program outcomes

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	**2**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO2	**2**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO3		-	-	-	-	**2**	-	-	-	-	-	-	-	-	-	-
CO4	**1**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO5	**1**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO6	**2**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Detailed Syllabus:

General Introduction: The cell, body fluids, Musculoskeletal system, respiratory system, gastrointestinal system, Nervous system, endocrine system and circulatory system.

Origin of Bio potentials: electrical activity of Excitable cells: the resting state, The active state, Volume conductor fields, Functional organization of the peripheral nervous system: Reflex are &Junction transmission.

The Electroneurogram (ENG): The H-Reflex, The Electromyogram (EMG), The Electrocardiogram (ECG), heart and the circulatory system, Electro conduction system of the heart and heart problems, ECG waveform and Physical significance of its wave features, Electrical behavior of cardiac cells, The standard lead system, The ECG preamplifier, DC ECG amplifier, Defibrillator protection circuit, Electro surgery Unit filtering, Functional blocks of ECG system, Multichannel physiological monitoring system, Common problems encountered and remedial techniques.

Blood Pressure: indirect measurement of blood pressure, korotkoff sounds, auscultatory method using sphygmo manometer, Oscillometric and ultrasonic noninvasive pressure measurement, Direct measurement of blood pressure H2O manometers, electronic manometry, Pressure transducers,. Pressure amplifier designs, Systolic, diastolic mean detector circuits

Blood flow and Volume Measurement: indicator dilution methods, Transit time flow meter, DC flow meter, Electromagnetic flow meter AC electromagnetic flow meter, Quadrature suppression flow meter, Ultrasonic flow meter, Continuous-wave Doppler flow meter, Electric impedance plethysmography, chamber plethysmography, Photo plethysmography.

Pulse Oximetr: Principles of Operation, Absorption Spectrum, Sensor design, Pulse oximeter, Therapeutic and Prosthetic Devices.

Cardiac Pacemakers: Lead wires and electrodes, Synchronous Pacemakers, rate responsive pacemaking, Defibrillators, cardioverters, electrosurgical unit, Therapeutic applications of laser, Lithotripsy Haemodialysis.

Reading:

1. John G Webster, Medical Instrumentation: Application and Design, John Wiley, 3rd Edition, 2012.
2. Joseph J. Carr& John M. Brown , Introduction to biomedical Equipment Technology, 4th Edition, Prentice Hall India, 2001

PH391	Advanced Materials	OPC	3 – 0 – 0	3 Credits

Pre-requisites: None.

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

CO1	Understand the synthesis and properties of nanomaterials
CO2	Evaluate the usefulness of nanomaterials in medicine, biology and sensing
CO3	Understand modeling of composite materials by finite element analysis
CO4	Differentiate superconducting materials
CO5	Understand the characteristics and uses of functional materials

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	**3**	-	-	-	-	-	-	-	-	-	-	-	**1**	-	-	**1**
CO2	-	-	-	-	-	**3**	-	-	-	-	-	-	-	-	-	-
CO3	**2**	-	-	-	-	-	-	-	-	-	-	-	**1**	-	-	-
CO4	**2**	-	-	-	-	-	-	-	-	-	-	-	**1**	-	-	-
CO5	**2**	-	-	-	-	-	-	-	-	-	-	-	-	-	**1**	-

Detailed Syllabus:

Nano Materials: Origin of nano technology, Classification of nano materials, Physical, chemical, electrical, mechanical properties of nano materials. Preparation of nano materials by plasma arcing, physical vapour deposition, chemical vapour deposition (CVD), Sol-Gel, electro deposition, ball milling, carbon nano tubes(CNT).Synthesis, preparation of nanotubes, nano sensors, Quantum dots, nanowires,nano biology, nanomedidcines.

Biomaterials: Overview of biomaterials. Biomaterials, bioceramics, biopolymers, tissue grafts, soft tissue applications, cardiovascular implants, biomaterials in ophthalmology, orthopeadiac implants, dental materials.

Composites: General characteristics of composites , composites classes, PMCs, MMCs, CMCs, CCCs, IMCs, hybrid composites, fibers and matrices, different types of fibers, whiskers, different matrices materials, polymers, metal, ceramic matrices, toughening mechanism, interfaces, blending and adhesion, composite modeling, finite element analysis and design.

Optical materials: Mechanisms of optical absorption in metals, semiconductors and insulators. Nonlinear optical materials, optical modulators, optical fibers. Display devices and materials photo-emissive, photovoltaic cells, charge coupled devices (CCD), laser materials.

Super conducting materials: Types of super conductors, an account of mechanism of superconductors, effects of magnetic field currents, thermal energy, energy gap, acoustic attenuation, penetration depth, BCS theory, DC and AC Josephson effects, high Tc superconductors, potential applications of superconductivity, electrical switching element, superconductor power transmission and transformers, magnetic mirror, bearings, superconductor motors, generators, SQUIDS etc.

Smart materials: An introduction, 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.

Surface Acoustic Wave (SAW) Materials and Electrets: Delay lines, frequency filters, resonators, and Pressure and temperature sensors, Sonar transducers. Comparison of electrets with permanent magnets, Preparation of electrets, Application of electrets.

Reading:

1. T.Pradeep, Nano: The Essentials; TaTa McGraw-Hill, 2008.
2. B.S. Murthy et al., Textbook of Nano science and Nanotechnology, University press
3. Krishan K Chawla, Composite Materials; 2^{nd} Edition, Springer 2006.

SM390	Marketing Management	OPC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Understand concepts and scope of marketing and market oriented strategic planning
CO2	Analyze macro level environment
CO3	Identify factors influencing consumer behavior in competitive global business environment
CO4	Identify tools and techniques for marketing management through integrated marketing communication systems.

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO2	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO3	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO4	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO5	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Detailed Syllabus:

Importance of Marketing, Scope of Marketing, Core Marketing concepts company orientation towards market place-production concept, Product concept, selling concept and Marketing concept.

Market oriented Strategic planning – Defining corporate Mission and Vision Statement at Corporate level and at Business unit level. Assigning resources to Strategic Business units through B.C.G Matrix and G.E Model.

Analyzing Macro environment-Demographic environment. Economic Environment, Technical Environment, Social-Cultural Environment and political – Legal Environment.

Components of Marketing information systems- Internal Records, Marketing intelligence, Marketing research and Marketing Decision support system.

Consumer Behavior- Buying Decision process and the factors influencing consumer Behavior- Psychological factors, social factors, cultural factors and personal factors.

Importance of Market segmentation, Target market selection and positioning.

Importance of new product development process and the various stages involved.

The concept of product lifecycle and the various strategies used by the marketer in each stage.

Product characteristics and classification, Product mix and product line decisions Branding Decisions, Building Brand Equity.

Importance of Pricing, Factors influencing pricing decisions. Various pricing methods-cost based and demand based methods.

Role of Marketing channels-Channel functions and channel levels channel Design and channel Management Decisions, Managing Retailing. Wholesaling and logistics. Importance of Electronic channels.

Importance of integrated Marketing communication. Advantages and Disadvantages of Various promotional tools- Advertising, Sales promotion, personal selling, publicity and public Relations and Direct marketing.

Reading:

1. Philip Kotler, Marketing Management, PHI, 14th Edition, 2013.
2. William Stonton & Etzel, Marketing Management, TMH, 13th Edition, 2013.
3. Rama Swamy & Namakumari, Marketing Management, McMillan, 2013.

BT440	BIOSENSORS	OPC	3 – 0 – 0	3 Credits

Pre-requisites: None.

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

CO1	Understand bio sensing and transducing techniques
CO2	Understand principles of linking cell components and biological pathways with energy transduction, sensing and detection
CO3	Demonstrate and appreciate the technical limits of performance of biosensor
CO4	Apply principles of engineering to develop bioanalytical devices and design of biosensors

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	**1**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO2	**1**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO3	-	-	**1**	-	-	-	-	-	-	-	-	-	-	-	-	-
CO4	-	-	**1**	-	-	-	-	-	-	-	-	-	-	-	-	-

Detailed Syllabus:

General principles: A historical perspective; Signal transduction; Physico-chemical and biological transducers; Sensor types and technologies, Definitions and Concepts Terminology and working vocabulary; Main technical definitions: calibration, selectivity, sensitivity, reproducibility, detection limits, response time.

Physico-chemical transducers: Electrochemical transducers (amperometric, potentiometric, conductimetric); optical transducers (absorption, fluorescence, SPR); Thermal transducers; piezoelectric transducers.

Biorecognition systems and Biosensor Engineering: Enzymes; Oligonucleotides and Nucleic Acids; Membrane receptors, Cells; Immunoreceptors; Limitations & problems. Immobilization of biomolecules, Methods for biosensors fabrication: self-assembled monolayers, screen printing, photolithography, micro-contact printing, MEMS.

Application of modern sensor technologies: Clinical chemistry; Test-strips for glucose monitoring; Urea determination; Implantable sensors for long-term monitoring; Environmental monitoring;

Technological process control; Food quality control; Forensic science benefits; Problems & limitations.

Reading:

1. Donald G. Buerk, Biosensors: Theory and Applications, 1st Edition, CRC Press, 2009.
2. Alice Cunningham, Introduction to Bioanalytical Sensors, John Wiley& Sons, 1998.
3. Brian R. Eggins, Chemical Sensors and Biosensors, John Wiley& Sons, 2003.

CH440	DATA DRIVEN MODELLING	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Identify disturbance models
CO2	Estimate parametric and non-parametric models
CO3	Determine the model structure
CO4	Validate the developed models

Course Articulation Matrix:

CO \ PO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO11	PO 12	PSO 1	PSO 2	PSO 3	PSO 4
CO1	**3**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO2	**2**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO3	-	**2**	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO4	-	-	-	**2**	-	-	-	-	-	-	-	-	-	-	-	-
CO5	**3**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Detailed syllabus

System Identification - Motivation and Overview. Models of Discrete-Time LTI Systems – Convolution equation. Difference equations, Transfer functions, State-space models, Discretization, Sampling and Hold operations, sampling theorem.

Disturbance models - random processes, representation of stationary processes, white-noise process, auto-covariance function (ACF), ARMA models. Parametric model structures - ARX, ARMAX, OE, BJ and PEM – structures and their applicability in real-time.

Linear Regression - Least Squares estimates, Statistical properties of LS Estimates. Weighted Least Squares, Recursive Least Squares, Maximum Likelihood Estimation and properties.

Estimation of non-parametric models - impulse / step response coefficients, frequency response models.

Estimation of parametric models - notions of prediction and simulation, predictors for parametric models, prediction-error methods, Instrumental Variable method.

Model Structure Selection and Diagnostics -estimation of delay and order, residual checks, properties of parameter estimates, model comparison and selection, model validation.

Reading:

1. Arun K. Tangirala. System Identification: Theory and Practice, CRC Press, 2014.
2. Karel J. Keesman, System Identification – An Introduction, Springer, 2011.
3. Nelles, O. Nonlinear System Identification, Springer-Verlag, Berlin, 2001.
4. Zhu, Y. Multivariable System Identification for Process Control, Pergamon, 2001.
5. Ljung, L. System Identification: Theory for the User, Prentice-Hall, 2nd Edition, 1999.
6. J. R. Raol, G. Girija, J. Singh, Modeling and Parameter Estimation of Dynamic Systems, The Institution of Electrical Engineers, 2004.
7. Rolf Johansson, System Modeling and Identification, Prentice Hall, 1993.

CH441	**FUEL CELL TECHNOLOGY**	**OPC**	**3 – 0 – 0**	**3 Credits**

(Not offered to Chemical Engineering Students)

Pre-requisites: None.

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

CO1	Understand fuel cell fundamentals.
CO2	Analyze the performance of fuel cell systems.
CO3	Demonstrate the operation of fuel cell stack and fuel cell system.
CO4	Apply the modeling techniques for fuel cell systems

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	PO1 1	PO 12	PSO 1	PSO 2	PSO 3	PSO 4
CO1	**2**	-	-	-	-	-	-	-	-	-	-	-	-	-	**1**	-
CO2	-	**3**	-	-	-	-	-	-	-	-	-	-	-	**2**	-	-
CO3	**3**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO4	-	-	-	-	**3**	-	-	-	-	-	-	-	**1**	-	-	-
CO5	**2**	-	-	-	-	-	-	-	-	-	-	-	-	-	**1**	-

Detailed syllabus

Overview of Fuel Cells: What is a fuel cell, brief history, classification, how does it work, why do we need fuel cells, Fuel cell basic chemistry and thermodynamics, heat of reaction, theoretical electrical work and potential, theoretical fuel cell efficiency.

Fuels for Fuel Cells: Hydrogen, Hydrocarbon fuels, effect of impurities such as CO, S and others.

Fuel cell electrochemistry: electrode kinetics, types of voltage losses, polarization curve, fuel cell efficiency, Tafel equation, exchange currents.

Fuel cell process design: Main PEM fuel cell components, materials, properties and processes: membrane, electrode, gas diffusion layer, bi-polar plates, Fuel cell operating conditions: pressure, temperature, flow rates, humidity.

Main components of solid-oxide fuel cells, Cell stack and designs, Electrode polarization, testing of electrodes, cells and short stacks, Cell, stack and system modeling

Fuel processing: Direct and in-direct internal reforming, Reformation of hydrocarbons by steam, CO_2 and partial oxidation, Direct electro-catalytic oxidation of hydrocarbons, carbon decomposition, Sulphur tolerance and removal , Using renewable fuels for SOFCs

Reading:

1. Hoogers G, Fuel Cell Technology Hand Book, CRC Press, 2003.
2. O'Hayre, R. P., S. Cha, W. Colella, F. B. Prinz, Fuel Cell Fundamentals, Wiley, 2006.
3. F. Barbir, PEM Fuel Cells: Theory and Practice, Elsevier/Academic Press, 2nd Edition, 2013.
4. Subhash C. Singal and Kevin Kendall, High Temperature Fuel Cells: Fundamentals, Design and Applications
5. Laminie J, Dicks A, Fuel Cell Systems Explained, 2nd Edition, John Wiley, New York, 2003.

CH442	DESIGN OF EXPERIMENTS	OPC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Design experiments for a critical comparison of outputs
CO2	Propose hypothesis from experimental data
CO3	Implement factorial and randomized sampling from experiments
CO4	Estimate parameters by multi-dimensional optimization

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	PO1 1	PO 12	PSO 1	PSO 2	PSO 3	PSO 4
CO1	-	-	**3**	-	-	-	-	-	-	-	-	-	**2**	**2**	-	-
CO2	-	-	-	**3**	-	-	-	-	-	-	-	-	**2**	**2**	-	-
CO3	-	-	-	**3**	-	-	-	-	-	-	-	-	**2**	**2**	-	-
CO4	-	-	**3**	-	-	-	-	-	-	-	-	-	**2**	**2**	-	-

Detailed syllabus

Introduction: Strategy of experimentation, basic principles, guidelines for designing experiments.

Simple Comparative Experiments: Basic statistical concepts, sampling and sampling distribution, inferences about the differences in means: Hypothesis testing, Choice of samples size, Confidence intervals, Randomized and paired comparison design.

Experiments with Single Factor; An example, The analysis of variance, Analysis of the fixed effect model, Model adequacy checking, Practical interpretation of results, Sample computer output, Determining sample size, Discovering dispersion effect, The regression approach to the analysis of variance, Nonparameteric methods in the analysis of variance, Problems.

Design of Experiments: Introduction, Basic principles: Randomization, Replication, Blocking, Degrees of freedom, Confounding, Design resolution, Metrology considerations for industrial designed experiments, Selection of quality characteristics for industrial experiments.

Parameter Estimation.

Response Surface Methods: Introduction, The methods of steepest ascent, Analysis of a second-order response surface, Experimental designs for fitting response surfaces: Designs for fitting the first-order model, Designs for fitting the second-order model, Blocking in response surface designs, Computer-generated (Optimal) designs, Mixture experiments, Evolutionary operation, Robust design, Problems.

Design and Analysis: Introduction, Preliminary examination of subject of research, Screening experiments: Preliminary ranking of the factors, active screening experiment-method of random balance, active screening experiment Plackett-Burman designs, Completely randomized block design, Latin squares, Graeco-Latin Square, Youdens Squares, Basic experiment-mathematical modeling, Statistical Analysis, Experimental optimization of research subject: Problem of optimization, Gradient optimization methods, Nongradient methods of optimization, Simplex sum rotatable design, Canonical analysis of the response surface, Examples of complex optimizations.

Reading:

1. Lazic Z. R., Design of Experiments in Chemical Engineering, A Practical Guide, Wiley, 2005.
2. Antony J., Design of Experiments for Engineers and Scientists, Butterworth Heinemann, 2004.
3. Montgomery D. C., Design and Analysis of Experiments, Wiley, 5th Edition, 2010.
4. Doebelin E. O., Engineering Experimentation: Planning, Execution, Reporting, McGraw-Hill, 1995.

CH443	CARBON CAPTURE, SEQUESTRATION AND UTILIZATION	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Identify the necessity of CO2 capture, storage and utilization
CO2	Distinguish the CO2 capture techniques
CO3	Evaluate CO2 Storage and sequestration methods
CO4	Assess Environmental impact of CO2 capture and utilization

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	-	**3**	-	-	-	-	-	-	-	-	-	-	**2**	-	-	-
CO2	**2**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO3	**2**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO4	-	-	-	-	-	**2**	**3**	-	-	-	-	-	-	-	-	-

Detailed syllabus

Introduction: Global status of CO_2 emission trends, Policy and Regulatory interventions in abatement of carbon footprint, carbon capture, storage and utilization (CCS&U)

CO_2 capture technologies from power plants: Post-combustion capture, Pre-combustion capture, Oxy-fuel combustion, chemical looping combustion, calcium looping combustion

CO_2 capture agents and processes: Capture processes, CO_2 capture agents, adsorption, ionic liquids, metal organic frameworks

CO2 storage and sequestration: Geological sequestration methods, Biomimetic carbon sequestration

CO2 Utilization: CO2 derived fuels for energy storage, polymers from CO2, CO2 based solvents, CO2 to oxygenated organics, Conversion into higher carbon fuels, High temperature catalysis

Environmental assessment of CO2 capture and utilization: Need for assessment, Green chemistry and environmental assessment tools, Life cycle assessment (LCA), ISO standardization of LCA, Method of conducting an LCA for CO2 capture and Utilization.

Reading:

1. Peter Styring, Elsje Alessandra Quadrelli, Katy Armstrong, Carbon dioxide utilization: Closing the carbon cycle, Elsevier, 2015.
2. GoelM,Sudhakar M, Shahi RV, Carbon Capture, Storage and, Utilization: A Possible Climate Change Solution for Energy Industry, TERI, Energy and Resources Institute, 2015.
3. AmitavaBandyopadhyay, Carbon Capture and Storage, CO_2 Management Technologies, CRC Press, 1st Edition, 2014.
4. Fennell P, Anthony B, Calcium and Chemical Looping Technology for Power Generation and Carbon Dioxide (CO_2) Capture, Woodhead Publishing Series in Energy: No. 82, 2015.
5. Mercedes Maroto-Valer M, Developments in Innovation in Carbon Dioxide Capture and Storage Technology: Carbon Dioxide Storage and Utilization, Vol 2, Woodhead Publishing Series in Energy, 1st Edition, 2014.

CY440	Chemical and Alternate Energy Systems	OPC	3 – 0 – 0	3 Credits

Pre-requisites: Knowledge in Chemistry and Physics

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

CO1	Understand the different functions and fields of application of various kinds of batteries, the importance of the chemistry of materials for their function, as well as their role in the energy system.
CO2	Describe the present research challenges in the field of chemical energy conversion and storage.
CO3	Understand the principle and material chemistry behind the functioning and efficiency of Electrochemical super capacitors and the fields of their applications.
CO4	Understand the principles behind energy conversion in solar cells and solar fuel systems, and discuss different methods for solar fuel production;
CO5	Explain the function of different kinds of solar cells and their mechanisms for charge separation.
CO6	Perform measurements and calculations of efficiency and quantum yield for solar cells.

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	PO1 1	PO 12	PSO 1	PSO 2	PSO 3	PSO 4
CO1	**1**	-	-	-	-	-	**1**	-	-	-	-	-	-	-	-	-
CO2	**1**	-	-	-	-	-	**1**	-	-	-	-	-	-	-	-	-
CO3	-	**1**	**1**		-	-	-	-	-	-	-	-	-	**1**	-	-
CO4	-	**1**	**1**	**1**	-	-	-	-	-	-	-	-	-	**1**	-	**1**
CO5	-	**1**	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO6	-	**1**	-	**1**	-	-	-	-	-	-	-	-	-	**1**	-	-

Detailed Syllabus:

1. **Introduction**

   Principles and mathematical models of electrochemical energy conversion and storage;

fundamental correlations on energy conversion and storage highlighting thermodynamics, reaction kinetics, transport phenomena, and electrostatics.

2. **Batteries**

   Electrochemical processes in different batteries, battery materials (bulk, interfaces and nanoproperties), mechanistic aspects and structural design of rechargeable batteries, metal-air batteries, safety and reliability of batteries.

3. **Fuel cells**

   8Principle of different kinds of fuel cells, porous gas electrodes, solid-oxide, molten-salt, acidic and alkaline fuel cells, proton and oxide transport phenomena, heat transport mechanism, safety and fields of applications.

4. **Solar cells**

   Principles for conversion of solar energy to electricity, basics of photovoltaic conversion technology and PV systems, fundamental calculations and measurement of efficiency of solar cells, charge collectors, charge separation and electron transport phenomena, technology of selective coating, different solar cell technologies (inorganic, inorganic, hybrid).

5. **Electrochemical super capacitors**

   Principles of different types of electrochemical super capacitors, electrostatic double-layer capacitors, electrochemical pseudo capacitors, mechanistic aspects and material chemistry, fields of applications.

6. **Chemical energy storage**

   Photobiology and photo biochemistry, artificial photosynthesis, catalysts for solar fuel production, genetic modification of photosynthetic organisms, photo biological fuel production, Chemically Modified Electrodes for Water Cleavage; Coordination Chemistry of Water Cleavage.

Reading:

1. O' Hayre, Ryan, Suk-Won Cha, Whitney Colella, Fritz B. Prinz, Fuel Cell Fundamentals. 3rd Edition, Wiley, 2016.
2. Newman, John, and Karen E. Thomas-Alyea, Electrochemical Systems. 3rd Edition, Wiley-Interscience, 2004.
3. Bard, Allen J., and Larry R. Faulkner, Electrochemical Methods: Fundamentals and Applications. 2nd Edition, Wiley, 2006.

4. Huggins, Robert, Advanced Batteries: Materials Science Aspects. Springer, 2010. .
5. Electrochemical Energy: Advanced Materials and Technologies (Electrochemical Energy Storage and Conversion, Pei Kang Shen, Chao-Yang Wang, San Ping Jiang (Ed), CRC, 2016
6. Solar Energy Conversion – Dynamics of Interfacidal Electron and Excitation Transfer, Piotrowiak, Laurie Peter, Heinz Frei and Tim Zhao, RSC, 2013.

CY441	Chemistry of Nanomaterials	OPC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Understand the state of art synthesis of nano materials
CO2	Characterize nano materials using ion beam, scanning probe methodologies, position sensitive atom probe and spectroscopic ellipsometry.
CO3	Analyze nanoscale structure in metals, polymers and ceramics
CO4	Analyze structure-property relationship in coarser scale structures
CO5	Understand structures of carbon nano tubes.

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	PO1 1	PO 12	PSO 1	PSO 2	PSO 3	PSO 4
CO1	**2**	-	-	-	-	-	-	-	-	-	-	-	-	**1**	**1**	-
CO2	**1**	-	-	-	**2**	-	-	-	-	-	-	-	-	-	-	-
CO3	**1**	-	-	-	**2**	-	-	-	-	-	-	-	-	-	-	**1**
CO4	**1**	-	-	-	**2**	-	-	-	-	-	-	-	-	-	-	**2**
CO5	**1**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**1**

Detailed Syllabus:

Introduction: Scope of Nano science and nanotechnology, Nano science in nature, classification of nanostructured materials, importance of nano materials.

Synthetic Methods: Chemical Routes (Bottom-Up approach):- Sol-gel synthesis, micro emulsions or reverse micelles, solvothermal synthesis, microwave heating synthesis and sonochemical synthesis. Physical methods (Top-Down approach):- Inert gas condensation, plasma arc technique, ion sputtering, Laser ablation, laser pyrolysis, and chemical vapour deposition method.

Techniques for characterization:

Diffraction Technique: - Powder X-ray diffraction for particle size analysis.

Spectroscopy Techniques: - Operational principle and applications of spectroscopy techniques for the analysis of nanomaterials, UV-VIS spectrophotometers and its application for band gap measurement.

Electron Microscopy Techniques: Scanning electron microscopy (SEM) and EDAX analysis, transmission electron microscopy (TEM), scanning probe microscopy (SPM).

BET method for surface area determination.

Dynamic light scattering technique for particle size analysis.

Reading:

1. T. Pradeep, NANO: The Essentials: McGraw-Hill, 2007.
2. B. S. Murty, P. Shankar, BaldevRai, BB Rath and James Murday, Textbook of Nanoscience and nanotechnology: Univ. Press, 2012.
3. Guozhong Cao, Nanostructures &Nanomaterials; Synthesis, Properties & Applications: Imperial College Press, 2007.
4. M.A. Shah and Tokeer Ahmad, Principles of Nanoscience and Nanotechnology: Narosa Pub., 2010.
5. ManasiKarkare, Nanotechnology: Fundamentals and Applications: IK International, 2008.
6. C. N. R. Rao, Achim Muller, K.Cheetham, Nanomaterials Chemistry, Wiley-VCH, 2007

CE440	Building Technology	OPC	3 – 0 – 0	3 Credits

Pre-requisites: None.

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

CO1	Apply basic principles to develop stable, sustainable and cost-effective building plans.
CO2	Identify effective measures for fire proofing, damp proofing, and thermal insulation.
CO3	Adopt standard building provisions for natural ventilation and lighting.
CO4	Identify different materials, quality and methods of fabrication & construction.

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	PO11	PO 12	PSO 1	PSO 2	PSO 3	PSO 4
CO1	**2**	-	-	-	-	-	-	-	-	-	-	-	**1**	-	-	-
CO2	-	**2**		-	-	-	-	-	-	-	-	-	-	-	-	-
CO3	**1**	-	**1**	-	-	-	-	-	-	-	-	-	-	-	-	-
CO4	-	**2**	-	-	-	-	-	-	-	-	-	-	-	-	-	**2**

Detailed Syllabus:

Overview of the course, basic definitions, Buildings – Types, components, economy and design, Principles of planning of buildings and their importance.

Definitions and importance of Grouping and circulation; Lighting and ventilation; How to consider these aspects during planning of building

Termite proofing: Inspection, control measures and precautions, Lighting protection of buildings: General principles of design of openings, Various types of fire protection measures to be considered while planning a building.

General requirements and extra requirements for safety against fire, special precautions, Vertical transportation in building – types of vertical transportation, Stairs, different forms of stairs, planning of stair cases, Other modes of vertical transportation – lifts, ramps, escalators.

Prefabrication systems in residential buildings – walls, openings, cupboards, shelves etc., planning and modules and sizes of components in prefabrication.

Planning and designing of residential buildings against the earthquake forces, Principles, Seismic forces and their effect on buildings.

Air conditioning – process and classification of air conditioning, Dehumidification. Systems of air-conditioning, ventilation, functional requirements of ventilation.

Acoustics, effect of noise, properties of noise and its measurements, Principles of acoustics of building. Sound insulation – importance and measures.

Plumbing services – water supply system, maintenance of building pipe line, Sanitary fittings, principles governing design of building drainage.

Reading:

1. Building Construction - Varghese, PHI Learning Private Limited, 2008
2. Building Construction - Punmia, B C, Jain, A J and Jain A J, Laxmi Publications, 2005.
3. Building Construction by S.P. Arora and S.P. Bindra – Dhanpatrai and Sons, New Delhi, 1996.
4. Building Construction – Technical Teachers Training Institute, Madras, Tata McGraw Hill, 1992.
5. National Building code of India, Bureau of Indian Standards, 2005.

CS440	Management Information Systems	OPC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Determine key terminologies and concepts including IT, marketing, management, economics, accounting, finance in the major areas of business.
CO2	Design, develop and implement Information Technology solutions for business problems.
CO3	Analysis of computing systems and telecommunication networks for business information systems.
CO4	Understand ethical issues that occur in business, evaluate alternative courses of actions and evaluate the implications of those actions.
CO5	Plan projects, work in team settings and deliver project outcomes in time.

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	**2**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO2	-	-	**1**	-	**1**	-	-	-	-	-	-	-	-	-	-	-
CO3	-	**2**	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO4	-	-	-	-	-	-	-	**2**	-	-	-	-	-	-	-	-
CO5	-	-	-	-	-	-	-	-	-	-	**2**	-	-	-	-	-

Detailed syllabus

Organization and Information Systems, Foundation Concepts, Information Systems in Business, the Components of Information Systems, Competing with Information Technology, Fundamentals of Strategic Advantage, Using Information Technology for Strategic Advantage.

Changing Environment and its impact on Business, Kinds of Information Systems.

Computer Fundamentals, Computer Hardware, and Computer Systems: End User and Enterprise Computing, Computer Peripherals: Input, Output, and Storage Technologies, Computer Software, Application Software, System Software, Computer System Management, Data Resource Management, Technical Foundations of Database Management, Managing Data Resources

Telecommunication and Networks, Telecommunications and Networks, the Networked Enterprise, Telecommunications Network Alternatives

System Analysis and Development and Models, Developing Business/IT Strategies, Planning Fundamentals, Implementation Challenges, Developing Business/IT Solutions, Developing Business Systems, Implementing Business Systems

Manufacturing and Service Systems Information systems for Accounting, Finance, Production and Manufacturing, Marketing and HRM functions, Enterprise Resources Planning (ERP), Choice of IT, Nature of IT decision, Managing Information Technology, Managing Global IT,

Security and Ethical Challenges, Security and Ethical Challenges, Security and Ethical, and Societal Challenges of IT, Security Management of Information Technology, Enterprise and Global Management of Information Technology

Reading:

1. Kenneth J Laudon, Jane P. Laudon, *Management Information Systems*, 10th Edition, Pearson/PHI, 2007.
2. W. S. Jawadekar, *Management Information Systems*, 3rd Edition, TMH, 2004.

EE440	NEW VENTURE CREATION	OPC	3–0– 0	3 Credits

Pre-requisites: None

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

CO1	Understand the process and practice of entrepreneurship and new venture creation
CO2	Identify entrepreneurial opportunities, preparation of a business plan for launching a new venture
CO3	Explore the opportunities in the domain of respective engineering disciplines for launching a new venture
CO4	Expose the students with the functional management issues of running a new venture

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	-	-	-	-	-	-	-	1	-	2	-	-	-	-	-	-
CO2	-	-	-	-	-	-	-	1	-	2	-	-	-	-	-	-
CO3	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-
CO4	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-

Detailed syllabus:

Entrepreneur and entrepreneurship: Entrepreneurship and Small Scale Enterprises (SSE), Role in Economic Development, Entrepreneurial Competencies, and Institutional Interface for SSE.

Establishing the Small Scale Enterprise: Opportunity Scanning and Identification, Market Assessment for SSE, Choice of Technology and Selection of Site, Financing the New/Small Enterprises, Preparation of the Business Plan, Ownership Structures and Organizational Framework.

Operating the Small Scale Enterprises: Financial Management Issues in SSE, Operational Management Issues in SSE, Marketing Management Issues in SSE, and Organizational Relations in SSE.

Reading:

1. Holt, Entrepreneurship: New Venture Creation, PHI (P), Ltd., 2001.
2. Madhulika Kaushik: Management of New & Small Enterprises, IGNOU course material, 1995
3. B S Rathore S Saini: Entrepreneurship Development Training Material, TTTI, Chandigarh, 1988.
4. P.C.Jain: A Hand Book for New Entrepreneur's, EDI-Faculty & External Experts, EDII, Ahmedabad, 1986.
5. J.B. Patel, D.G Allampalli: A Manual on How to Prepare a Project Report, EDII, Ahmedabad, 1991.
6. J B Patel, S SModi, A Manual on Business Opportunity Identification and Selection, EDII, Ahmedabad, 1995.

EE441	PRINCIPLES OF ELECTRIC POWER CONVERSION	OPC	3–0– 0	3 Credits

Pre-requisites: None

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

CO1	Understand the basics in the electric power conversion using power switching devices
CO2	Evaluate the conversion for range of renewable energy sources with the help of available electrical machines drives
CO3	Analyze the different energy storage systems
CO4	Identify the various Industrial and domestic applications

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	**1**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO2	**1**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO3	**1**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO4	**1**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Detailed syllabus:

Power Electronic Devices and Converters: V-I characteristics of SCR, MOSFET and IGBT. Phase controlled rectifiers, DC-DC converters and Inverters.

Applications to Electric Drives: Speed control of DC motor, Induction motors, PMSM and BLDC drives

Applications to Renewable Energy: Introduction to solar cell, solar panels, MPPT, wind and other renewable energy sources, Integration of renewable energy sources to the grid.

Energy Storage Systems: Study of automotive batteries, SMF, pumped storage systems, super-capacitors, fly wheels - applications, Li-ion batteries and applications to electric vehicles.

Domestic And Industrial Applications: Induction heating, melting, hardening, lighting applications and their control, UPS, battery chargers

Reading:

1. M.H.Rashid: Power Electronics-circuits, Devices and applications, Prentice Hall India, New Delhi, 2009.
2. P.S.Bhimbra: Power Electronics, Khanna publishers, New Delhi, 2012.
3. Ned Mohan, Undeland and Robbin: Power electronics converters, applications and design, John Willey &Sons,Inc. NewYork, 2006.

EC440	Electronic Measurements and Instrumentation	OPC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Apply knowledge of instruments for effective use
CO2	Select suitable instruments for typical measurements.
CO3	Identify various transducers to measure strain, temperature and displacement.
CO4	Understand data acquisition system and general purpose interfacing bus.

Mapping of course outcomes with program outcomes

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-
CO2	-	2	-	-	2	-	-	-	-	-	-	-	-	-	-	-
CO3	-	-	-	-	2	-	-	-	-	-	-	-	-	2	-	-
CO4	1	-	-	-		-	-	-	-	-	-	-	-	-	-	-

Detailed syllabus

Measurement And Error: Sensitivity, Resolution, Accuracy and precision, absolute and Relative types of errors, Statistical analysis, Probability of and Limiting errors, Linearity.

Instruments: D'Arsonval movement and basic principles of Measurement of Voltage, Current and Resistance in instruments. Analog and Digital Multimeters, Measurement of time and Frequency – Digital Frequency Meter and applications.

Impedance Measurement: Kelvin Bridge; Megger; Maxwell, Hay and Shering Bridges. Q-meter; Noise and Interference reduction techniques in Measurement Systems.

Oscilloscopes: Block diagram, probes, Deflection amplifier and delay line, Trigger Generator, Coupling, Automatic Time Base and Dual Trace Oscilloscopes, Pulse Measurements, Delayed Time Base, Analog Storage, Sampling and Digital Storage Oscilloscopes.

Special instruments: Wave Analyzer, Harmonic Distortion Analyzer, Spectrum Analyzer, FFT Analyzer.

Transducers (Qualitative Treatment Only): Classification and selection of Transducers, Introduction to strain, Load, force, Displacement, Velocity, Acceleration, Pressure and Temperature Measurements.

Introduction to Data Acquisition Systems (DAS): Block Diagram, Specifications and various components of DAS.

General purpose Instrumentation Bus (GP-IB): Protocol, SCPI Commands and Applications to DSO and DMM.

Reading:

1. Oliver and Cage, Electronic Measurements and Instrumentation, McGraw Hill, 2009
2. Helfrick Albert D. and Cooper William D., Electronic Instrumentation & Measurement Techniques, PHI, 2008.
3. D.A. Bell, Electronic Instrumentation and Measurements, 3rd Edition, Oxford, 2013.

HS440	Corporate Communication	OPC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Understand corporate communication culture
CO2	Prepare business letters, memos and reports
CO3	Communicate effectively in formal business situations
CO4	Exhibit corporate social responsibility and ethics
CO5	Practice corporate email, mobile and telephone etiquette
CO6	Develop good listening skills and leadership qualities

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	PO1 1	PO 12	PSO 1	PSO 2	PSO 3	PSO 4
CO1	-	-	-	-	-	-	-	-	-	3		-	-	-	-	-
CO2	-	-	-	-	-	-	-	-	-	2	3	-	-	-	-	-
CO3	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-
CO4	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-
CO5	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-
CO6	-	-	-	-	-	-	-	-	1		-	-	-	-	-	-

Detailed Syllabus:

Importance of Corporate communication - Introduction to and definition of corporates – Communication, process, patterns and channels of communication- Barriers to communication and strategies to overcome them- Evolution of corporate culture- Role and contribution of individual group and organization - Role of psychology in communication.

Oral Communication- Techniques for improving oral fluency-Speech mechanics-Group Dynamics and Group Discussion – Debate and oral presentations.

Written Communication- Types and purposes- Writing business reports, and business proposals- Memos, minutes of meetings- Circulars, persuasive letters- Letters of complaint- ; language and formats used for drafting different forms of communication. Internal and external communication.

Corporate responsibility- Circulating to employees vision and mission statements- ethical practices- Human rights -Labour rights-Environment- governance- Moral and ethical debates surrounding -Public Relations - Building trust with stakeholders.

Corporate Ethics and Business Etiquette- Integrity in communication-Harmful practices and communication breakdown- Teaching how to deal with tough clients through soft skills. Body language- Grooming- Introducing oneself- Use of polite language- Avoiding grapevine and card pushing – Etiquette in e-mail, mobile and telephone.

Listening Skills - Listening- for information and content- Kinds of listening- Factors affecting listening and techniques to overcome them- retention of facts, data and figures- Role of speaker in listening.

Leadership Communication Styles - Business leadership -Aspects of leadership-qualities of leader- training for leadership-delegation of powers and ways to do it-humour-commitment.

Reading:

1. Raymond V. Lesikar, John D. Pettit, Marie E. Flatley Lesikar's Basic Business Communication – 7th Edition: Irwin, 1993
2. Krishna Mohan and Meera Banerji, Developing Communication Skills: Macmillan Publishers India, 2000
3. R.C. Sharma & Krishna Mohan Business Correspondence and Report Writing: – 3rd Edition Tata McGraw-Hill, 2008
4. Antony Jay & Ross Jay, Effective Presentation, University Press, 1999.
5. Shirley Taylor, Communication for Business, Longman, 1999

MA440	Optimization Techniques	OPC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Formulate and solve linear Programming Problems
CO2	Determine the optimum solution to constrained and unconstrained problems.
CO3	Apply dynamic programming principle to Linear programming problems.
CO4	Determine the integer solutions to Linear Programming Problems.

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	-	**2**		-	-	-	-	-	-	-	-	-	-	**1**	-	-
CO2	-	**1**	**2**	-	-	-	-	-	-	-	-	-	-	-	-	**2**
CO3	-	-	-	-	-	-	-	-	-	-	**1**	-	-	**2**	-	-
CO4	-	-	-	-	-	-	-	-	-	-	**1**	-	**1**	-	-	-

Detailed Syllabus:

Linear Programming: Introduction and formulation of models, Convexity, Simplex method, Big-M method, Two-phase method, Degeneracy, non-existent and unbounded solutions, revised simplex method, duality in LPP, dual simplex method, sensitivity analysis, transportation and assignment problems, traveling salesman problem .

Nonlinear Programming: Introduction and formulation of models, Classical optimization methods, equality and inequality constraints, Lagrange multipliers and Kuhn-Tucker conditions, quadratic forms, quadratic programming problem, Wolfe's method.

Dynamic Programming: Principle of optimality, recursive relations, solution of LPP.

Integer Linear Programming: Gomory's cutting plane method, Branch and bound algorithm, Knapsack problem, linear 0-1 problem.

Reading:

1. Kanti Swarup, Man Mohan and P.K.Gupta, Introduction to Operations Research, S.Chand & Co., 2006
2. J.C. Pant, Introduction to Operations Research, Jain Brothers, New Delhi, 2008.
3. N.S.Kambo, Mathematical Programming Techniques, East-West Pub., Delhi, 1991.

MA441	Operations Research	OPC	3 – 0 – 0	3 Credits

Prerequisites: None

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

CO1	Formulate and solve linear programming problems
CO2	Determine optimum solution to transportation problem
CO3	Determine average queue length and waiting times of queuing models.
CO4	Determine optimum inventory and cost in inventory models.

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	-	2		-	-	-	-	-	-	-	-	-	-	1	-	-
CO2	-	1	2	-	-	-	-	-	-	-	-	-	-	-	-	2
CO3	-	-	-	-	-	-	-	-	-	-	1	-	-	2	-	-
CO4	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-

Detailed Syllabus:

Linear Programming: Formulation and graphical solution of LPP's. The general LPP, slack, surplus and artificial variables. Reduction of a LPP to the standard form. Simplex computational procedure, Big-M method, Two-phase method. Solution in case of unrestricted variables. Dual linear programming problem. Solution of the primal problem from the solution of the dual problems.

Transportation Problems: Balanced and unbalanced Transportation problems. Initial basic feasible solution using N-W corner rule, row minimum method, column minimum, least cost entry method and Vogel's approximation method. Optimal solutions. Degenracy in Transportation problems.

Queueing Theory: Poisson process and exponential distribution. Poisson queues - Model (M/M/1):(∞/FIFO) and its characteristics.

Elements of Inventory Control: Economic lot size problems - Fundamental problems of EOQ. The problem of EOQ with finite rate of replenishment. Problems of EOQ with shortages - production instantaneous, replenishment of the inventory with finite rate. Stochastic problems with uniform demand (discrete case only).

Reading:

1. Kanti Swarup, Man Mohan and P.K.Gupta, Introduction to Operations Research, S. Chand & Co., 2006
2. J.C. Pant, Introduction to Operations Research, Jain Brothers, New Delhi, 2008.
3. N.S.Kambo: Mathematical Programming Techniques, East-West Pub., Delhi, 1991.

ME440	ALTERNATIVE SOURCES OF ENERGY	OPC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Identify renewable energy sources and their utilization.
CO2	Understand basic concepts of solar radiation and analyze solar thermal systems for its utilization.
CO3	Understand working of solar cells and its modern manufacturing technologies.
CO4	Understand concepts of Fuel cells and their applications
CO5	Identify methods of energy storage.
CO6	Compare energy utilization from wind energy, geothermal energy, biomass, biogas and hydrogen.

Mapping of course outcomes with program outcomes

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	-	**3**	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO2	**3**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO3	**1**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO4	**2**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO5	-	**2**	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO6	**2**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Detailed Syllabus:

Introduction: Overview of the course; Examination and Evaluation patterns; Global warming; Introduction to Renewable Energy Technologies

Energy Storage: Introduction; Necessity of Energy Storage; Energy Storage Methods

Solar Energy: Fundamentals; Solar Radiation; Estimation of solar radiation on horizontal and inclined surfaces; Measurement of solar radiation data

Solar Thermal systems: Introduction; Basics of thermodynamics and heat transfer; Flat plate collector; Evacuated Tubular Collector; Solar air collector; Solar concentrator; Solar distillation; Solar cooker; Solar refrigeration and air conditioning; Thermal energy storage systems

Solar Photovoltaic systems: Introduction; Solar cell Fundamentals; Characteristics and classification; Solar cell: Module, panel and Array construction; Photovoltaic thermal systems.

Wind Energy: Introduction; Origin and nature of winds; Wind turbine siting; Basics of fluid mechanics; Wind turbine aerodynamics; wind turbine types and their construction; Wind energy conversion systems

Fuel cells: Overview; Classification of fuel cells; operating principles; Fuel cell thermodynamics

Biomass Energy: Introduction; Photosynthesis Process; Biofuels; Biomass Resources; Biomass conversion technologies; Urban waste to energy conversion; Biomass gasification. Other forms of Energy: Introduction: Nuclear, ocean and geothermal energy applications; Origin and their types; Working principles

Reading:

1. Sukhatme S.P. and J.K.Nayak, Solar Energy - Principles of Thermal Collection and Storage, Tata McGraw Hill, New Delhi, 2008.
2. Khan B.H., Non-Conventional Energy Resources, Tata McGraw Hill, New Delhi, 2006.
3. J.A. Duffie and W.A. Beckman, Solar Energy – Thermal Pro

ME441	ROBUST DESIGN	OPC	3 – 0 – 0	3 Credits

Pre-requisites: None.

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

CO1	Understand stages in engineering design and concept of robust design.
CO2	Develop quality loss functions and S/N ratios for S, N and L type objective functions.
CO3	Identify control and noise factors for a given product or process.
CO4	Conduct experiments using DOE concepts to decide the optimal setting of parameters
CO5	Apply quality loss function approach for fixing the component tolerances.

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	**2**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO2	-	-	**2**	-	-	-	-	-	-	-	-	-	-	-	-	-
CO3	-	**1**	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO4	-	-	-	**1**	-	-	-	-	-	-	-	-	-	-	-	-
CO5	**2**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Detailed syllabus

Introduction: Taguchi's quality philosophy, causes of performance variation, concept of robust design, stages in product / process design, need for experimentation, QFD, process flow analysis, cause and effect diagram.

DesignofExperiments**:**Principlesofexperimentation,Basicconceptsofprobabilityandstatistics, Comparison of two means and two variances, Comparison of multiple (more than two) means & Anova, Factorial designs, fractional factorial designs, orthogonal arrays, standard orthogonal arrays&interactiontables,modifyingtheorthogonalarrays,selectionofsuitableorthogonalarray design, analysis of experimental data.

Parameter Design**:** Loss function, average quality loss, S/N ratios, objective functions, selection of control & noise factors and their levels, strategy for systematics amplifying of noise, classification of control factors, inner-array and outer-array design, data analysis, selection of optimum levels/values for parameters.

Tolerance Design: Experiments, selection of tolerances to be tightened, fixing the final tolerances.

Reading:

1. Taguchi G, Chowdhury S and Taguchi S, Robust Engineering, TMH, 2000.
2. Ross PJ, Taguchi Techniques for Quality Engineering, TMH, 2000.

MM440	Metallurgy for Non-Metallurgists	OPC	3-0-0	03 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.
CO2	Explain different fabrication techniques.
CO3	Correlate the microstructure, properties, processing and performance of materials.
CO4	Select metal/alloy for engineering applications.

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Detailed syllabus:

Introduction to Metallurgy: Metals and Alloys classification, engineering applications of metals/alloys.

Structure of Metals and Alloys: Nature of Metallic Bonding, Crystal Structures of Metals, Structure of Alloys, Imperfections in Crystals.

Mechanical Properties: Plastic Deformation Mechanisms, Tensile, Creep, Fatigue, Fracture

Strengthening Mechanisms: Strain Hardening, Grain Size Refinement, Solid Solution Strengthening, Precipitation Hardening

Fabrication and Finishing of metal products: Metal Working and Machining

Testing of Metals: Destructive and Non-Destructive Testing, Inspection and Quality Control of Metals.

Engineering Alloys: Steel Products and Properties, Cast Irons, Tool Steels and High Speed Steels, Stainless Steels, selective non-ferrous metals and alloys.

Heat Treatment: Annealing, Normalizing, Hardening and Tempering.

Material selection processes: Case studies

Readings:

1. M. F. Ashby, Engineering Metals, 4th Edition, Elsevier, 2005.
2. R. Balasubramaniam (Adapted): Calister's Materials Science and Engineering, 7th Edition, Wiley India (P) Ltd, 2007.
3. R. Abbaschian, L. Abbaschian, R.E. Reed-Hill, Physical Metallurgy Principles, East-West Press, 2009.
4. V Raghavan, Elements of Materials Science and Engineering- A First Course, 5th Edition, PHI Publications, 2011.

PH440	Nanomaterials and Technology	OPC	3 – 0 – 0	3 Credits

Prerequisites: None

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

CO1	Understand synthesis and properties of nanostructured materials.
CO2	Analyze magnetic and electronic properties of quantum dots
CO3	Understand structure, properties and applications of Fullerenes and Carbon nanotubes.
CO4	Understand applications of nanoparticles in nanobiology and nanomedicine

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	**3**	-	-	-	-	-	-	-	-	-	-	-	**2**	-	-	-
CO2	-	-	-	**3**	-	-	-	-	-	-	-	-	-	-	-	**2**
CO3	**3**	-	-	-	-	-	-	-	-	-	-	-	-	**1**	-	-
CO4	-	-	**2**	-	-	-	-	-	-	-	-	-	-	**1**	-	-

Detailed Syllabus:

General properties of Nano materials: Origin of nanotechnology. Classification of nanomaterials. Fullerene, carbon, Nanotubes (CNT's), Nanoparticles. Physical, Chemical, Electrical, Optical, Magnetic and mechanical properties of nanomaterials.

Fullerenes and Carbon Nanotubes (CNT's): Introduction: Synthesis and purification. Preparation of fullerenes in the condensed phase, Transport, mechanical, physical properties of CNT's.

Investigation and manipulating materials in the Nanoscale: Electron microscope, scanning probe microscopes, optical microscopes for Nano science and Technology, X-Ray Diffraction.

SAMs and clusters: Growth process. Patterning monolayers. Types of clusters. Bonding and properties of clusters.

Semi conducting Quantum Dots: Introduction: Synthesis of Quantum Dots. Electronic structure of Nanocrystals, properties.

Nanobiology: Interaction between Biomolecules and Nanoparticle surfaces. Different types of Inorganic materials used for the synthesis of Hybrid Nano-bio assemblies. Nanoprobes for Analytical Applications.

Nanosensors: Nanosensors based on optical properties. Nanosensors based on quantum size effects. Nanobiosensors.

Nanomedicines: Developments of nanomedicines. Nanotechnology in Diagnostic Applications, materials for use in Diagnostic and therapeutic Applications.

Reading:

1. T. Pradeep, Nano: The Essentials; Tata McGraw-Hill, 2008.
2. W.R. Fahrner, Nanotechnology and Nanoelectronics; Springer, 2006.
3. Rechard Booker and Earl Boysen, Nanotechnology, Willey, 2006.

PH441	Biomaterials and Technology	OPC	3 – 0 – 0	3 Credits

Prerequisites: None

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

CO1	Understand the structure and properties of biomaterials
CO2	Classify implant biomaterials
CO3	Evaluate biocompatibility of implants
CO4	Identify appropriate biomaterials for specific medical applications

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
CO2	2	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
CO3	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	3
CO4	-	3	-	1	-	-	-	-	-	-	-	-	-	-	3	-

Detailed Syllabus:

Overview of biomaterials: Historical developments, impact of biomaterials, interfacial phenomena, tissue responses to implants.

Structure and properties of biomaterials: Crystal structure of solids, phase changes, imperfections in solids, non-crystalline solids, surface properties of solids, mechanical properties, surface improvements.

Types of biomaterials: Metallic implant materials, ceramic implant materials, polymeric implant materials composites as biomaterials.

Characterization of materials: Electric properties, optical properties, X-ray absorption, acoustic and ultrasonic properties.

Bio implantation materials: Materials in ophthalmology, orthopedic implants, dental materials and cardiovascular implant materials.

Tissue response to implants: Normal wound healing processes, body response to implants, blood compatibility, and structure – property relationship of tissues.

Reading:

1. Joon Park, R.S. Lakes , Biomaterials an introduction; 3rd Edition, Springer, 2007
2. Sujatha V Bhat, Biomaterials; 2nd Ed., Narosa Publishing House, 2006.

SM440	Human Resource Management	OPC	3 – 0 – 0	3 Credits

Pre-requisites: None

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

CO1	Understand principles, processes and practices of human resource management.
CO2	Apply HR concepts and techniques in strategic planning to improve organizational performance.
CO3	Understand tools to manage HR systems and procedures.

Mapping of course outcomes with program outcomes

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	PSO 1	PSO 2	PSO 3	PSO 4
CO1	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-
CO2	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO3	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-

Detailed Syllabus:

Introduction to Human Resource Management, Objectives, Scope and Significance of HRM, Functions of HRM, Problems and Prospects in HRM, Environmental scanning.

Human Resource Planning, Demand Forecasting Techniques, Supply Forecasting Techniques, Analyzing work and designing jobs, Recruitment and Selection, Interviewing Candidates.

Human Resource Development, Orientation, Training and Development, Management Development, Performance Appraisal and Employee Compensation, Factors Influencing Employee Remuneration and Challenges of Remuneration.

Industrial Relations, Industrial Disputes and Discipline, Managing Ethical Issues in Human Resource Management, Workers Participation in Management, Employee safety and health, Managing Global Human Resources and Trade Unions

International HRM, Future of HRM and Human Resource Information Systems

Reading:

1. Aswathappa, Human Resource Management — TMH. 2010.
2. Garry Dessler and Biju Varkkey, Human Resource Management, PEA, 2011.

3. Noe& Raymond, HRM: Gaining a Competitive Advantage, TMH, 2008.
4. Bohlander George W, Snell Scott A, Human Resource Management, Cengage Learning, 2009.