Course Structure

B. Tech. - Minerals and Metallurgical Engineering

Applicable to those admitted through JEE from 2019 onwards

Department of Fuel, Minerals and Metallurgical Engineering

Indian Institute of Technology (ISM) Dhanbad

Dhanbad, Jharkhand, India

(September - 2019)

Course Structure

SEMESTER III

S. No.	Subject ID	Subject Name	Lecture (L)	Tutorial (T)	Practical (P)	Credit Hours	Contact Hours
1	FMC201	Colloids and interfacial phenomena	3	0	0	9	3
2	FMC202	Heat and mass transfer	3	0	0	9	3
3	FMC203	Physical separation processes for coal and minerals	3	0	0	9	3
4	FME221	Particle technology (ESO 1)	3	0	0	9	3
5	E/SO 2	E/SO	3	0	0	9	3
6	FMC251	Particle technology laboratory	0	0	2	2	2
7	FMC252	Physical separation processes laboratory	0	0	2	2	2
					Total Credit	**49**	**19**

SEMESTER IV

S. No.	Subject ID	Subject Name	Lecture (L)	Tutorial (T)	Practical (P)	Credit Hours	Contact Hours
1	FMC204	Electrochemistry and corrosion	3	0	0	9	3
2	FMC205	Thermodynamics and kinetics	3	0	0	9	3
3	FMC206	Phase transformation and heat treatment	3	0	0	9	3
4	FMC207	Fine particle processing for coal and minerals	3	0	0	9	3
5	FME222	Introduction to fuel technology (ESO 3)	3	0	0	9	3
6	FMC253	Fine particle processing laboratory	0	0	2	2	2
7	FMC254	Introduction to fuel technology laboratory	0	0	2	2	2
				Total Credit		**49**	**19**

SEMESTER V

S. No.	Subject ID	Subject Name	Lecture (L)	Tutorial (T)	Practical (P)	Credit Hours	Contact Hours
1	FMC301	Coal and mineral process equipment selection	3	0	2	11	5
2	FMC302	Extractive metallurgy	3	0	0	9	3
3	OE1	Open Elective	3	0	0	9	3
4	HSS1	HSS	3	0	0	9	3
5	E/SO4	ESO	3	0	0	9	3
6	FMC351	Extractive metallurgy laboratory	0	0	3	3	3
					Total Credit	**50**	**20**

SEMESTER VI

S. No.	Subject ID	Subject Name	Lecture (L)	Tutorial (T)	Practical (P)	Credit Hours	Contact Hours
1	FMC303	Mechanical metallurgy	3	0	0	9	3
2	FMC304	Coal and mineral processing plant design	3	0	2	9	5
3	MS1	MS	3	0	0	9	3
4	OE2	OE	3	0	0	9	3
5	OE3	OE	3	0	0	9	3
6	FMC352	Heat treatment and mechanical metallurgy laboratory	0	0	3	3	3
7	FMC391	Industrial Tour	0	0	0	0	0
			Total Credit			**48**	**20**

SEMESTER VII

S. No.	Subject ID	Subject Name	Lecture (L)	Tutorial (T)	Practical (P)	Credit Hours	Contact Hours
1	DE2	Dept. Elective	3	0	0	9	3
2	DE3	Dept. Elective	3	0	0	9	3
3	OE4	OE	3	0	0	9	3
4	OE5	OE	3	0	0	9	3
5	OE6	OE	3	0	0	9	3
6	UGP	UGP-1 (Zero-Credit Compulsory)	0	0	0	0	3
7	DC12*	Internship/Training/Seminar/Field-Excursion	0	0	0	0	3
			Total Credit			**45**	**21**

SEMESTER VIII

S. No.	Subject ID	Subject Name	Lecture (L)	Tutorial (T)	Practical (P)	Credit Hours	Contact Hours
1	DE4	Dept. Elective	3	0	0	9	3
2	DE5	Dept. Elective	3	0	0	9	3
3	OE7	OE	3	0	0	9	3
4	DC13*	UGP-2	0	0	0	9	3
5	HSS/MS	HSS/MS	3	0	0	9	3
			Total Credit			**45**	**15**

****Internship and Training shall start after the IV Semester****, from Summer/winter vacation* ***for at least 12 weeks before graduation*** *and Viva–Voce for the internship shall be held at the beginning of each subsequent semester beginning with V Semester, while the project will continue up to the end of the VIII Semester****.***

Note: 1. OE allotment to be based on CGPA up to previous semester, Total strength of students to be decided by the Dept/Teacher concerned.

2. In place of practicals, a few courses with tutorials can be offered by the Department.

SUBJECT LIST

S. No.	Subject ID	Subject Name	Lecture (L)	Tutorial (T)	Practical (P)	Credit Hours	Contact Hours
DEPARTMENT CORE							
1	FMC201	Colloids and interfacial phenomena	3	0	0	9	3
2	FMC202	Heat and mass transfer	3	0	0	9	3
3	FMC203	Physical separation processes for coal and minerals	3	0	0	9	3
4	FMC204	Electrochemistry and corrosion	3	0	0	9	3
5	FMC205	Thermodynamics and kinetics	3	0	0	9	3
6	FMC206	Phase transformation and heat treatment	3	0	0	9	3
7	FMC207	Fine particle processing for coal and minerals	3	0	0	9	3
8	FMC301	Coal and mineral process equipment selection	3	0	2	11	5
9	FMC302	Extractive metallurgy	3	0	0	9	3
10	FMC303	Mechanical metallurgy	3	0	0	9	3
11	FMC304	Coal and mineral processing plant design	3	0	2	11	5
PRACTICAL							
1	FMC251	Particle technology laboratory	0	0	2	2	2
2	FMC252	Physical separation processes laboratory	0	0	2	2	2
3	FMC253	Fine particle processing laboratory	0	0	2	2	2
4	FMC254	Introduction to fuel technology laboratory	0	0	2	2	2
5	FMC351	Extractive metallurgy laboratory	0	0	3	3	3
6	FMC352	Heat treatment & mechanical metallurgy laboratory	0	0	3	3	3
DEPARTMENT ELECTIVES (offered by FMME)							
1	FMD461	Computational techniques and modelling	3	0	0	9	3
2	FMD462	Process control and plant layout	3	0	0	9	3
3	FMD463	Non-ferrous extractive metallurgy	3	0	0	9	3
4	FMD464	Mineral policy and economics	3	0	0	9	3
5	FMD525	Iron and steel making	3	0	0	9	3
6	FMD526	Cement technology	3	0	0	9	3
7	FMO543	Waste processing and management	3	0	0	9	3
8	FMO544	Clean coal technology	3	0	0	9	3
9	FMO545	Equipment design	3	0	0	9	3
OPEN ELECTIVES (offered by FMME)							
1	FMO431	Elements of mineral engineering	3	0	0	9	3
2	FMO541	Characterization of materials	3	0	0	9	3
ESO (offered by FMME)							

1	FME221	Particle technology	3	0	0	9	3
2	FME222	Introduction to fuel technology	3	0	0	9	3

Course Contents

COLLOIDS AND INTERFACIAL PHENOMENA

Course Type	Course Code	Name of Course	L	T	P	Credits
DC	FMC201	Interfacial phenomena	3	0	0	9

Course Objective
Fundamentals of colloids and interfacial phenomena and its applications in mineral and metals processing.
Learning Outcomes
• Characterization of colloidal systems and interfaces. • Fundamentals, characterization, and applications of liquid-gas, liquid-liquid, solid-gas, solid-liquid, and charges interfaces. • Interactions between colloidal particles and factors resulting in colloidal stability. • Experimental techniques for characterization of interfaces and colloidal systems. • Applications of colloids and interfacial phenomena in industrial applications with special emphasis on mineral and metals processing operations.

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1	**Colloidal systems:** definition; importance; particle characterization; classification of colloidal systems; structural characteristics; motion of particles in liquid media: viscosity, sedimentation, Brownian motion, diffusion; osmotic pressure.	3	Introduction to colloids and characterization of particles constituting colloidal systems
2	**Liquid-gas and liquid-liquid interfaces:** surface and interfacial tension; Kelvin's equation; measurement of surface and interfacial tensions; adsorption at interface; surfactants; Gibbs adsorption equation; micelle formation; critical micelle concentration; spreading; monomolecular films; emulsions and foams.	6	Concept of surface and interfacial tensions, effect of curvature and temperature on surface tension, measurement of surface tension, adsorption at interfaces, introduction to emulsions and foams.
3	**Solid-gas interface:** Adsorption of gases on solids; physical versus chemical adsorption; classification of physical adsorption; Langmuir, Freundlich, and BET adsorption isotherms; determination of total surface area of porous solids, heat of adsorption; effect of solid structure and composition on adsorption.	6	Modes of adsorption of gases on solids, adsorption isotherms, characterization of porous solids.
4	**Solid-liquid interface:** Contact angle and wetting; Young's equation; spreading, adhesion, and immersion wetting; measurement of contact angle; ore flotation; detergency; adsorption from solution.	6	Introduction, characterization, and mechanisms of wetting phenomenon.
5	**Charged interfaces:** Electric double layer; zeta potential; electrokinetic phenomena: electrophoresis, electroosmosis, streaming potential, sedimentation potential; Smoluchowski and Huckel equation.	6	Fundamentals, characterization and applications of electric double layer.
6	**Colloidal interaction and stability:** van der Waals interaction; DLVO theory; electrostatic and steric interactions; flocculation.	3	Aggregation and stability of colloidal dispersions.

7	**Methods to characterize colloidal systems:** Viscometry, microelectrophoresis, sedimentation, surface tension; static and dynamic light scattering.	3	Experimental techniques for characterizing colloidal systems.
8	Industrial applications of colloids and interfacial phenomena especially in minerals, metals processing.	6	Industrial applications of colloids and interfacial phenomena.

Text Books:

S. No.	Resource/Book Name	Author(s)/Editor(s)	Publisher
1	Introduction to colloid and surface chemistry	Duncan J. Shaw	Butterworth-Heinemann

HEAT AND MASS TRANSFER

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	FMC202	Heat and Mass Transfer	3	0	0	9

Course Objective
Fundamentals of transport phenomena and its application in metals processing
Learning Outcomes
Governing equations for solving microscopic and macroscopic problems related to fluid flow, heat and mass transfer with applications in metals processing.

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1	Fluid mechanics: Continuity equation; Navier-Stokes equation; turbulence; Engineering Bernoulli's equations; hydrocyclone; electrostatic precipitator; supersonic flow in nozzles; Darcy's law	8	Viscous properties of fluids, momentum equation for solving laminar flow problems, introduction to turbulence, mechanical energy balance equation for solving macroscopic flow problems, flow in porous media.
2	Heat transfer: Steady and unsteady conduction; General heat transfer equation; natural and forced convection; heat transfer in turbulent flows; heat transfer coefficient; Newtonian cooling; radiation heat transfer; packed and fluidized beds; phase transformation; solidification of metals; heat exchanger design; furnace design	17	Mechanism for transport of thermal energy, equations governing heat transfer by conduction, convection, and radiation, macroscopic treatment of heat transfer, applications in metals processing.
3	Solid state diffusion: Diffusive and convective fluxes; diffusion mechanisms; diffusion coefficient; Kirkendall effect; uphill diffusion; steady and unsteady diffusion; estimation of diffusion coefficients; Carburization; phase transformation; homogenization of alloys	8	Mechanism of diffusion in solids, governing equations for solid state diffusion, applications in physical metallurgy.
4	Convection mass transfer: Natural and forced convection mass transfer; general mass transfer equation; diffusion through stagnant and moving gas film; chemical vapour deposition; mass transfer coefficient and its applications; degasification	5	Governing equations for mass transfer in fluid systems, macroscopic treatment of mass transfer, real-life applications.
5	Interphase mass transfer: Two-resistance mass transfer theory; mixed control reactions; oxidation of metals; vaporization	2	Chemical reaction coupled mass transfer between two phases

Text Books:

S. No.	Resource/Book Name	Author(s)/Editor(s)	Publisher
1	Transport phenomena in metals processing	D. R. Poirier, G. H. Geiger	Springer International Publishers
2	Engineering in process metallurgy	R. I. L. Guthrie	Oxford University Press
3	Elements of chemical reaction engineering	H. Scott Fogler	Prentice Hall

PHYSICAL SEPARATION PROCESSES FOR COAL AND MINERALS

Course Type	Course Code	Name of Course	L	T	P	Credits
DC	FMC203	Physical separation processes for coal and minerals	3	0	0	9

Course Objective
To learn about the principles, construction and operation of physical separation processes
Learning Outcomes
Upon successful completion of this course, students will have the • knowledge of the need, scope and applications of density separation • understanding of the basic principles of density separation • familiarisation with the different techniques used for thedensity separation of coal and minerals • knowledge of the important factors that affect the performance of industrial density separation technologies • knowledge about the performance assessment of density separators and their benchmarking

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcomes
1	**Introduction to physical separation processes:** Basic Principles of Separation Processes; different types of processes employed in mineral engineering: density, magnetic, electrical, surface, optical separations. coal/ore characteristics required for applying these processes. Calculations of yield, recovery, ratio of concentration, enrichment ratio and separation efficiency.	3	Introduction to the subject, the different concentration techniques and their scopes, applications and limitations. Introduction to the basic terminology related to concentration, general calculations related to concentration
2	**Washability analysis:**Sink-float test-work for coal and minerals and data interpretation.	3	Knowledge of the washability analysis test-work
3	**Jigging:** Principles of jigging including the major phenomena, equal settling/jigging particles, v-t curves, jig cycles and their applications, different types of jigs-mechanical and pneumatic jigs their merit and demerits, variables affecting jigging	5	Knowledge of the applications and basic principles involving industrial jigging, its operation and performance optimisation
4	**Dense medium separation:** Principles of dense medium separation, stability of media suspension, preparation of dense medium, types of solids and their properties to use as dense medium. Factors affecting dense medium stability and consistency. Different types of static and dynamic separators e.g, Dense Medium Baths (deep and shallow) and Dense Medium Cyclones, Vorsyl Separator, Tri-flo separator etc., typical media preparation and media recovery equipment and circuits	7	Awareness of the different dense medium separation techniques and their application, construction, operation and performance determining factors. Knowledge of the need of a medium recovery circuit and its general layout

5	**Stub-cyclones, Teetered Bed Separators, Reflux Classifiers:** Construction, operation and applications. **Flowing film concentration:** Principles. Tabling, influence of various factors affecting tabling, mathematical analysis, different types of tables. Spiral concentration, application of spiral concentrators, Reichert's cone	5	Familiarisation with the different techniques used for the gravity concentration of intermediate size particles, with their construction, operation and performance optimisation
7	**Enhanced gravity concentration:** Different gravity concentrators like multi-gravity separator, Knelson concentrator, Kelsey jig, Falcon separator etc.	2	Knowledge of the gravity separation techniques applied for the concentration of fine particles
8	**Performance analysis of density separators:** Estimation of cleaning performance, calculation of performance parameters: cut-density, E_P, Error area, imperfection organic efficiency, ash reduction factor, yield reduction factor, etc.	3	Comprehension of the procedure applied for the performance assessment of density separators and interpretation of the results
9	**Magnetic Separation:** Principles of magnetic separation, types of magnetic materials; construction, operation and performance factors of different magnetic separators; typical applications	7	Learning of the principles, construction, operation and important factors for magnetic separation equipment
10	**Electrical Separation:** Principles of electrostatic separation. Electrical properties of materials. Lifting and pinning effect, corona discharge. Construction, operation and performance factors of different electrical separators. Auxiliary equipment. Multi roll separator, plate and screen separators, ESP, tribo-electric separator	4	Understanding the principles of electrical separation and knowledge of the construction, operation and important factors of electrical separators

Text Books:

S. No.	Resource/Book Name	Author(s)/Editor(s)	Publisher
1	Wills' Mineral Processing Technology	Barry A. Wills James Finch	Butterworth-Heinemann
2	Coal Preparation	Joseph W. Leonard III	Society for Mining, Metallurgy and Exploration
3	Coal Preparation Technology. Volume 1 and 2.	D. G. Osborne	Graham and Trotman
4	Magnetic methods for the treatment of minerals	J. Svoboda	Elsevier

Reference Books:

S. No.	Resource/Book Name	Author(s)/Editor(s)	Publisher
1	Mineral Processing Design and Operation: An Introduction	A. Gupta and D.S. Yan	Elsevier
2	Introduction to Mineral Processing	Errol G. Kelly, David J. Spottiswood	Wiley
3	Gravity Concentration Technology (Developments in Mineral Processing, 5)	Richard O. Burt, Chris Mills	Elsevier
4	SME Mineral Processing and Extractive Metallurgy Handbook	Robert C. Dunne, S. Komar Kawatra, Courtney A. Young	Society for Mining, Metallurgy and Exploration
5	High Gradient Magnetic Separation	Richard Gerber, Robert R. Birss	Research Studies Press

PARTICLE TECHNOLOGY

Course Type	Course Code	Name of Course	L	T	P	Credits
ESO	FME221	Particle Technology	3	0	0	9

Course Objective
The objective of the course is to learn about the fundamentals of particle characterisation, comminution and classification and get familiarised with the different technologies used, with focus on the equipment, their construction, operation and performance optimization
Learning Outcomes
Upon successful completion of this course, students will have • the knowledge about the sampling principles and methods as required for various analyses • the knowledge of the various properties of particles and their characterisation • the understanding of the importance and application of comminution and classification operations in industry • the understanding about the underlying principles and phenomena of all relevant size reduction and size separation units used in the industry • the knowledge of the construction, operation, application and performance enhancement of industrial size reduction and size separation equipment • the information about the performance analysis methodologies and mass and water balancing of industrial comminution-classification circuits

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1	**Introduction:** definition of mineral, rock, ore, gangue, tenor. Unit operations, conceptual flow diagram to represents sequence of material in plants. Particle properties and their relevance to mineral processing	2	Familiarisation with the fundamentals of mineral engineering
2	**Sampling:** Definition, need, methods of sampling (solids and slurries), Gy's law of sampling, estimation of minimum amount of sample required, BIS standard for sampling, accurate sampling of solids and slurry	2	Knowledge of the principles and standard methods used for the collection of solid, liquid and slurry samples
3	**Particle size and size distribution:** Geometrical diameters, equivalent or derived diameters, statistical diameters to designate the size of the irregular particles, in sieve and sub-sieve sizes, and their measurement techniques Particle size distribution and quantification, different methodologies **Size distribution functions:** Gaudin-Schumann, Rosin-Rammler, Gaudin-Meloy, Broadbent and Calcott	3	Knowledge of the concept of size and its different definitions and of the various methods applied for their measurement, representation and interpretation of size distribution data
4	**Surface area and shape measurement:** Direct and indirect methods, permeability, gas adsorption, Volume and porosity measurements, Bulk solids properties – bulk density, true density.	2	Knowledge of the various methods applied for the measurements of surface area and shape of particles and other bulk properties
5	**Basics of size reduction:** Fundamentals of size reduction, modes of fracture comminution laws, drop shatter tests and shatter index, single particle breakage and packed bed breakage; basic principles of crushing and grinding. grindability indices	3	Understanding of the meaning, scope and importance of comminution and mechanism of comminution, with knowledge of the relevant material testing techniques
6	**Crushing:** Construction & operational features of different crusher: objectives, forces of breakage;	7	Familiarisation with the different crushing equipment used in the

	design, operation and maintenance of jaw, gyratory, cone, single and double roll crushers, sizers, hammer mills, ring granulators and rotary breakers, high compression rolls. performance aspects. in-pit and portable crushers.		industry, their construction, operation, merits, demerits, operational and design parameters and their performance analysis
7	**Grinding:** Principles, construction & operational features of grinding mills: ball, rod, pebble, autogenous, sag and fluid energy mills, mills used in power plants and cement industry; mill liners; feed entry and product discharge mechanisms; open- and closed-circuit grinding; application of mills; effect of process parameters on mill performance	7	Familiarisation with the different milling equipment and techniques used in minerals, power and cement industries, their construction, operation, merits, demerits, and operational and design parameters
8	**Industrial screening:** need and importance of size separation, fundamentals of industrial screening; dry and wet screening; classification of screens; different types of industrial screens. pre-scrubbing and other processes to improve screening efficiency. Screen performance measurement, factors affecting screen performance.	5	Understanding the principles and mechanism, need and scope of screening and knowledge about the different types of industrial screens, their applications, construction, operation, important factors and performance analysis
9	**Classification:** Settling of solids in fluids, settling velocities for Stokesian and Newtonian conditions, Reynolds number and its application, settling ratios. Different types of classifiers used in mineral industry: Hydrocyclones, Mechanical Classifiers, Efficiency of classifiers; Solids and water balance calculations.	8	Understanding the principles of classification in fluids and familiarisation with the different industrial classifiers, their construction, operation, important factors, performance analysis and circuit balancing

Text Books:

S. No.	Resource/Book Name	Author(s)/Editor(s)	Publisher
1	Wills' Mineral Processing Technology	Barry A. Wills James Finch	Butterworth-Heinemann
2	Introduction to Mineral Processing	Errol G. Kelly, David J. Spottiswood	John Wiley and Sons

Reference Books:

S. No.	Resource/Book Name	Author(s)/Editor(s)	Publisher
1	Mineral Processing Design and Operation: An Introduction	A. Gupta and D.S. Yan	Elsevier
2	Mineral Processing Plant Design	Andrew L. Mular, Roshan Boman Bhappu	Society of Mining Engineers (AIME)

PARTICLE TECHNOLOGY LABORATORY

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	FMC251	Particle technology laboratory	0	0	2	2

Course Objective
To impart practical exposure to the different particle characterisation and size reduction techniques
Learning Outcomes
After completion of the course, the students will have hands-on knowledge of • particle characterisation techniques • construction and operation of laboratory scale models of common industrial crushers

- effect of different parameters on size reduction

Unit No.	Name of Experiment	Practical Hours	Learning Outcome
1	Sampling – methods and accuracy	2	Knowledge of the different sampling methods and their accuracy
2	Dry and wet sieving	2	Knowledge of particle size distribution analysis through sieving and understanding of the effect of water addition in sieving
3	Relative density, bulk density Abrasion index determination	2	Knowledge of the techniques used for the determination of relative and bulk densities and abrasion index
4	Sub-sieve size distribution analysis using Andreasen pipette	2	Familiarisation with the process of sub-sieve size analysis with Andreasen pipette
5	Sub-sieve size distribution analysis using beaker decantation method	2	Familiarisation with the process of sub-sieve size analysis with beaker decantation method
6	Sub-sieve size distribution analysis using Cyclosizer	2	Familiarisation with the process of sub-sieve size analysis with Cyclosizer
7	Roll crusher – importance of set and feed material	2	Understanding the construction and operation of a roll crusher and the effect of its set and the feed material on its performance
8	Jaw crusher – importance of type and feed material	2	Understanding the construction and operation of a jaw crusher and the effect of its type and the feed material on its performance
9	Effect of crusher type on breakage of material	2	Understanding of the difference in breakage characteristics of different crushers
10	Grinding – effect of residence time	2	Understanding the construction and operation of a ball mill and the effect of residence time on its performance
11	Grinding – effect of ball size distribution	2	Understanding the effect of ball size distribution on the grinding mill performance
12	Grinding – effect of ball charge	2	Understanding the effect of ball load on the performance of a ball mill

PHYSICAL SEPARATION PROCESSES LABORATORY

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	FMC252	Physical separation processes laboratory	0	0	3	3

Course Objective

To obtain practical exposure to the different physical separation techniques used for the quality upgradation of coal and minerals

Learning Outcomes

After completion of the course, the students will have hands-on knowledge of

- the technique used for assessing the potential of ores/coal for density separation
- the workings of laboratory models of common industrial density separators
- the technique used for characterising the magnetic content of an ore
- the workings of laboratory models of common industrial magnetic separators

Unit No.	Name of Experiment	Practical Hours	Learning Outcome

1	Washability analysis	3	Familiarisation with the methodology adopted for determining the potential and ease of density separation
2	Effect of time on jigging performance	3	Understanding the effect of time on jigging performance
3	Effect of feed solids concentration on spirals performance	3	Understanding the effect of feed solids concentration on its performance
4	Mozley mineral separator – effect of wash water flow rate and oscillation amplitude	3	Understanding the construction and operation of a jig and the effect of wash water flow rate and oscillation amplitude on its performance
5	Wilfley table – effect of wash water flow rate	3	Understanding the construction and operation of a Wilfley table and the effect of wash water flow rate on its performance
6	Performance analysis of density separator	3	Knowledge of the methodology of performance analysis of density separators
7	Davis' tube magnetics test – effect of magnetic field intensity	3	Understanding the construction and operation of a Davis'tube magnetics tester and the effect of magnetic field intensity on the determination of magnetics content
8	Induced roll magnetic separator – effect of magnetic field intensity and roll speed	3	Understanding the construction and operation of a induced roll magnetic separator and the effect of magnetic field intensity and roll speed on its performance
9	WHIMS – effect of field intensity and matrix type	3	Understanding the construction and operation of a WHIMS and the effect of magnetic field intensity and matrix type on its performance
10	Perm roll magnetic separator-effect of roll speed and feed rate	3	Understanding the construction and operation of a perm roll magnetic separator and the effect of roll speed and feed rate on its performance
11	Performance analysis of magnetic separators	3	Knowledge of the methodology of performance analysis of density separators

ELECTROCHEMISTRY AND CORROSION

Course Type	Course Code	Name of Course	L	T	P	Credits
DC	FMC204	Electrochemistry and Corrosion	3	0	0	9

Course Objective
Fundamentals of electrochemical cells and its applications in metals finishing, batteries, effluent treatment, and corrosion in metals and alloys
Learning Outcomes
• Thermodynamics and kinetics of electrochemical reactions. • Principles of electrochemical cell design. • Industrial applications: electrochemical metal finishing and effluent treatment. • Battery characteristics and components, types of batteries. • Fundamentals and types of corrosion and corrosion protection in metals.

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1	Electrochemical cells;Faraday's law; half-cell potential; EMF series; Nernst equation.	2	Knowledge of the thermodynamics of

			electrochemical reactions.
2	Concept of overpotential; activation overpotential; exchange current density; polarization diagram; mass transfer in electrochemical systems; concentration overpotential; limiting current density; current distribution; principles of cell design; electrochemical measurements.	10	Understanding charge and mass transfer kinetics in electrochemical reaction and principles of cell design.
3	Electroplating of metals and alloys; electroless deposition; anodizing; electropolishing; electropickling; electrophoretic painting; electroforming.	6	Principles and practice of metal finishing operations.
4	Battery characteristics; battery components; types of batteries: Pb-acid, Mn-C; lithium ion; fuel cells	5	Knowledge of the fundamentals and types of batteries
5	Eco-cell; fluidized bed electrode; electrodialysis; electrofiltration.	2	Principles and applications of electrochemical effluent treatment.
6	Principles of corrosion in metals and alloys; mixed potential; types of corrosion: galvanic corrosion, crevice corrosion, pitting corrosion, stress corrosion, intergranular corrosion, high temperature corrosion; corrosion kinetics; corrosion protection	12	Fundamentals of corrosion, types of corrosion, principles and practice of corrosion protection

Text Books:

S. No.	Resource/Book Name	Author(s)/Editor(s)	Publisher
1	Corrosion Engineering	Mars G. Fontana	McGraw Hill Education

Reference Books:

S. No.	Resource/Book Name	Author(s)/Editor(s)	Publisher
1	Electrochemical Methods – Fundamentals and Applications	Allen J. Bard, Larry R. Faulkner	John Wiley and Sons
2	Modern Electrochemistry	John O'M. Bockris, Amulya K. N. Reddy	Kluwer Academic Publishers

THERMODYNAMICS AND KINETICS

Course Type	Course Code	Name of Course	L	T	P	Credits
DC	FMC205	Thermodynamics and Kinetics	3	0	0	9

Course Objective
Basic understanding of the laws of thermodynamics and equilibrium in chemical/metallurgical systems and chemical reaction kinetics.
Learning Outcomes
• Laws of thermodynamics and its applications, equilibrium in chemical reactions, phase equilibria in one and two component systems. • Rate law in chemical reaction kinetics, definition and basic design of ideal and non-ideal reactors.

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
	Thermodynamics		
1	Importance of thermodynamics; basic definitions: universe, system, surroundings, boundary, homogeneous and	2	Introduction to thermodynamics and

	heterogeneous systems, intensive and extensive properties, state and path functions, classification of processes, zeroth law of thermodynamics; equations of state; mixture of ideal gases; real gases.		associated terminology.
2	Work and heat; state and path functions; reversible and irreversible processes; first law of thermodynamics; internal energy; enthalpy; isothermal and adiabatic expansion; Joule-Thomson expansion; examples of some thermodynamic cycles	4	Concepts and applications related to the first law of thermodynamics.
3	Second law of thermodynamics; heat engines; Carnot cycle; concept of entropy; criterion for equilibrium; entropy and disorder; Gibbs free energy; Maxwell's relations; Gibbs-Helmholtz equation	7	Concepts and applications related to the second law of thermodynamics and criteria for equilibrium.
4	Heat of formation; heat of reaction; heat capacity; Hess's law; third law of thermodynamics; calorimetry	3	Calculation and measurement of enthalpy changes in endothermic and exothermic reactions.
5	Multicomponent systems; partial molar quantities; chemical potential; Gibbs-Duhem equation; homogeneous and heterogeneous chemical equilibrium	4	Concepts related to equilibrium in multicomponent systems.
6	One-component phase equilibria: phase diagram; Gibbs phase rule; Clayperon equation; critical point and supercritical fluids; Clausius-Clayperon equation	2	Understand phase transition and phase co-existence in a one-component system
7	Two-component phase equilibria: Ellingham diagram; Raoult's law; Henry's law; concept of activity, Gibbs-Duhem equation, regular solution, phase diagram, Lever's rule; Sievert's law	7	Understand phase equilibrium in gas-solid and gas-liquid systems
Chemical Kinetics			
8	Thermodynamics versus kinetics; reaction mechanism in homogeneous and heterogeneous systems; rate controlling step; rate equation; experimental determination of rate equation parameters; batch and continuous reactors; stirred tank reactors; plug flow reactors; reactor conversion and sizing; residence time distribution.	10	Fundamentals of chemical reaction kinetics and its application in ideal/non-ideal reactors

Text Books:

S. No.	Resource/Book Name	Author(s)/Editor(s)	Publisher
1	Lecture Notes | Thermodynamics & Kinetics | Chemistry | MIT OpenCourseWare (https://ocw.mit.edu/courses/chemistry/5-60-thermodynamics-kinetics-spring-2008/lecture-notes/)	Massachusetts Institute of Technology	Massachusetts Institute of Technology
2	Introduction to the Thermodynamics of Materials	David R. Gaskell, David E. Laughlin	CRC Press
3	Elements of chemical reaction engineering	H. Scott Fogler	Prentice Hall

PHASE TRANSFORMATION AND HEAT TREATMENT

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	FMC206	Phase transformation and heat treatment	3	0	0	9

Course Objective
Principles of phase transformation and heat treatment with emphasis on steels and non-ferrous alloys

Learning Outcomes
• Crystal structure in metals. • Thermodynamics and kinetics of solid-liquid and solid-solid phase transformations. • Phase diagrams and microstructure evolution in solid-liquid and solid-solid transformations. • Heat treatment techniques in for modification of mechanical properties Fe-C systems (steels) and non-ferrous metals.

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1	Types of bonding; lattice and unit cell; crystal systems and Bravais lattices; atomic packing; voids; Miller indices	2	Introduction to atomic bonding and crystal structure
2	Gibbs free energy vs. composition diagram; types of binary phase diagrams; Lever's rule; phase rule	4	Phase diagrams in metallic systems
3	Thermodynamics of solidification; nucleation and growth; pure metal solidification; alloy Solidification: redistribution of solute during solidification; constitutional under-cooling; dendrites growth; structure of casting and ingots; types of casting	6	Thermodynamics, microstructure, and applications of solid to liquid transformation
4	Solid state phase transformation: nucleation and growth; overall transformation rate	3	Thermodynamics and kinetics of solid state phase transformation
5	Iron-carbon alloy system: iron-Fe_3C diagram; nucleation and growth of pearlite; cooling of hypo-eutectoid; eutectoid; and hyper-eutectoid steels; types and microstructure of cast iron	3	Phase diagram and microstructure in iron-carbon alloy system
6	JMKA (Avrami) kinetics; TTT and CCT Diagrams; bainitic transformation; martensitic transformation	3	Kinetics of solid-state transformation in iron-carbon system
7	Annealing; normalizing; hardening; tempering; recovery/recrystallization/grain growth; hardenability of steels (Jominy end quench method)	3	Heat treatment processes of steel
8	Role of alloying elements in steels	2	Effect of alloying elements on phase transformation in steels.
9	Thermomechanical treatment of steels: controlled rolling; hot-cold rolling; ausforming; isoforming	3	Thermomechanical treatment of steels
10	Heat treatment of aluminium alloys: designations; aluminium alloy series; heat treatable and non-heat treatable alloys; precipitation and sequence; effect of deformation and temperature; heat treatment of titanium and magnesium alloys; heat treatment of titanium and magnesium alloys	5	Fundamentals of heat treatment of non-ferrous alloys
11	Carburizing; nitriding; carbonitriding; laser surface cladding; flame hardening; induction hardening	3	Surface hardening methods
12	Batch Furnaces; continuous furnaces; salt bath furnaces; Temperature measurement and control: calibration; thermocouples and pyrometers	2	Furnace and controls used in heat treatment

Text Books:

S. No.	Resource/Book Name	Author(s)/Editor(s)	Publisher
1	Solid-State Phase Transformations	V. Raghavan, Morris Cohen	Plenum Press
2	Principles of Heat Treatment of Steel	R. C. Sharma	New Age International
3	Heat Treatment: Principles and	T. V. Rajan, C. P. Sharma, Ashok	Prentice Hall

	Techniques	Sharma	

FINE PARTICLE PROCESSING FOR COAL AND MINERALS

Course Type	Course Code	Name of Course	L	T	P	Credits
DC	FMC207	Fine particle processing for coal and minerals	3	0	0	9

Course Objective
To give idea of various mineral processing techniques at fine particle size and idea of dewatering technology.
Learning Outcomes
Upon successful completion of this course, students will: • be able to acquire the knowledge about the processing of particles at fine size range. • be able to dewater the wet materials generated from mineral processing plants.

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1	**Introduction:** Fundamentals of fine particle processing.	3	Understanding of basic approach for selection of process based on the properties of material.
2	**Froth Flotation:** Flotation theory, flotation reagents, laboratory flotation tests. Types of flotation: emulsion flotation, carrier flotation, selective flotation, floc-flotation, skin flotation, reverse flotation, electro flotation. Flotation machine features and functions. Design, selection and sizing. Conventional and modern flotation machines - Column flotation, Jameson Cell etc.	15	This unit will help student in understanding the beneficiation of fine particles based on the surface properties.
3	**Oil agglomeration:** Principles, process equipment, practices, reagents and application	4	This will help students in selecting the process and equipment related to oil agglomeration process.
4	**Fluidization:** Principles, process equipment and practices Applications of fluidisation	2	This will enable students to select process related to fluidization for the processing of fines.
5	**Flocculation and selective flocculation:** Principles, process equipment, practices, reagents, and their selection	4	This will help students to understand the behaviour of particles in liquid to define the process of dewatering and selective flocculation.
6	**Thickening and filtration:** Thickening fundamentals, basic machine features, different types of thickeners – conventional thickener, high rate thickener, lamella thickener, deep cone thickener, paste thickening technology etc. Filtration principles, constant rate and constant pressure filtration, filters – vacuum drum filter, vacuum disc filter, filter press, horizontal belt filter. Design, selection and sizing of thickeners and filters	9	This will help student to understand the separation of liquid from slurry i.e. dewatering related processes.
7	**Drying:** Principles and methods	2	Knowledge of the principles and practice of industrial drying

Text Book:

S. No.	Resource/Book Name	Author(s)/Editor(s)	Publisher
1	Mineral Processing Design and Operation: An Introduction	A. Gupta and D.S. Yan	Elsevier

Reference Books:

S. No.	Resource/Book Name	Author(s)/Editor(s)	Publisher
1	Introduction to Mineral Processing	Errol G. Kelly, David J. Spottiswood	John Wiley and Sons
2	Principles of Mineral Dressing	Antoine Marc Gaudin	Tata McGraw Hill
3	Unit Operations of Chemical Engineering	Warren L. McCabe, Julian C. Smith, Peter Harriott	McGraw Hill
4	Perry's Chemical Engineers' Handbook	Don W. Green, Marylee Z. Southard	McGraw Hill
5	Solid-Liquid Separation	Ladislav Svarovsky	Butterworth-Heinemann

INTRODUCTION TO FUEL TECHNOLOGY

Course Type	Course Code	Name of Course	L	T	P	Credits
DC	FME222	Introduction to fuel technology	3	0	0	9

Course Objective
The main aim of the course is to give an introduction to the different types of fossil fuels. The emphasis of the course will be on the characterizations and utilizations of solid fuels, basics of liquid and gaseous fuels.
Learning Outcomes
At the end of this course students would have the knowledge of • coal characterisation and its utilisation in different thermochemical conversion processes • design of coal utilisation equipment • biomass characterisation and utilisation.

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1	Introduction to energy resources, Indian perspective, Origin and formation of coal: Different theories on coal formation, Rank of coal, classification of coal.	3	Students will get overview of energy resources, including coal
2	Coal Properties: Chemical, Physical and Plastic properties: Proximate analysis, Ultimate analysis, coal petrography, Gross calorific value, Net calorific value, Free Swelling Index, Caking Index, Roga Index, LTGK, plastometer, dilatometer, Estimation of total moisture. Hardness, determination of HGI. Porosity, density, specific heat, thermal conductivity, Selection of coal for various processes.	10	Students will learn various characterization techniques for coal
3	Behaviour of coal at elevated temperature**.** Fundamental and mechanism of coal carbonization, Types of carbonization and processes, Coke properties, Formed coke, bi-products of coal carbonization.	5	Knowledge on fundamentals of coal carbonization.
4	Fundamentals of coal combustion, mechanism of combustion, different coal firing systems, stoichiometric calculations.Clean coal technology for power, cement and steel industries.	6	Knowledge on coal combustion.
5	Design of coke ovens, coal combustion and gasification systems. Classification and selection of refractories. Fuel and heat losses in combustion and carbonization units.	7	Knowledge on design of coal utilization equipment, selection of refractories
6	Biomass and its utilization: types of biomass, biomass utilisation	4	Knowledge on biomass,

	process, Production of biochar, bio oils/fuel for various industrial applications, Utilization of various waste materials as fuel, Introduction to fuel cell		waste materials as fuel. Fuel cell.
7	Classification of crude petroleum, characteristics of petroleum and their products. Classification of gaseous fuels, production of gaseous fuel from coal. Liquefaction of coal, other utilization potential of coal. CBM/CMM, Gas hydrates, shale gas	4	Introductory knowledge on liquid and gaseous fuel

Text Books:

S. No.	Resource/Book Name	Author(s)/Editor(s)	Publisher
1	Fuels and Combustion	Samir Sarkar	Universities Press

Reference Books:

S. No.	Resource/Book Name	Author(s)/Editor(s)	Publisher
1	Elements of Fuels, Furnaces & Refractories	O. P. Gupta	Khanna Publishers
2	Fuels, Furnaces and Refractories	R. C. Gupta	Prentice Hall
3	The Chemistry and Technology of Coal	James P. Speight	CRC Press

FINE PARTICLE PROCESSING LABORATORY

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	FMC253	Fine particle processing laboratory	0	0	2	2

Course Objective
To give practical knowledge of processing of coal and minerals at fine size range.
Learning Outcomes
Upon successful completion of this course, students will: • have the practical experience of processing of fines. • be able to understand the practical application of flocculation, thickening and filtration process in dewatering of fines.

Exp. No.	Description	Practical Hours	Learning Outcome
1	Processing of copper ores using froth flotation and study the effect of collector dosage on flotation kinetics.	2	Understanding of beneficiation of sulphide ores using froth flotation technique and its kinetic behaviour.
2	Processing of lead-zinc ores using froth flotation and study the effect of frother dosage on grade and recovery.	2	Understanding of beneficiation of sulphide ores using selective froth flotation.
3	Processing of coal fines using froth flotation and study the effect of pulp density on the quality of clean coal.	2	This will help students in selecting in optimizing the reagent dosage and selecting flotation cell size.
4	Processing of iron ore fines using selective flocculation and study the effect of reagent dosage on the performance.	2	This will help students to understand the application of selective flocculation in beneficiation.
5	Study of the effect of oil dosage on the processing of coal/mineral using oil	2	This will help student to understand use of oil agglomeration in fines beneficiation.

	agglomeration.		
6	Processing of ore/coal fines using advanced gravity separation technique.	2	This will give exposure of advanced gravity separation of fines.
7	Study the effect of process parameters (pH, pulp density, flocculant dosage) on the settling and thickening behaviour of coal fines at given flocculant dosage.	2	The students shall be able to understand the dewatering of fines in coal washery and role of process parameters.
8	Study the effect of process parameters (pH, pulp density, flocculant dosage) on the settling and thickening behaviour of iron ore fines.	2	The students shall be able to understand the dewatering of minerals in process plants and effect of process parameters.
9	Dewatering of fines using vacuum/pressure filtration.	2	This will give idea of filtration and its use in dewatering of fines.
10	Demonstration of laboratory model vacuum drum filter and vacuum disc filter.	2	This will give comparative idea of application of filters in dewatering of fines.
11	Demonstration of laboratory model thickener and pressure filter.	2	This will give idea of application of dewatering of fines using various equipment.

Text Books:

S. No.	Resource/Book Name	Author(s)/Editor(s)	Publisher
1	Laboratory Experiments in Mineral Engineering	S. Venkatachalam, S. N. Degaleesan	Oxford & IBH Publishing

Reference Books:

S. No.	Resource/Book Name	Author(s)/Editor(s)	Publisher
1	Analytical methods for ores and minerals	B. H. Khawas	I.K. International Publishing House

INTRODUCTION TO FUEL TECHNOLOGY LABORATORY

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	FMC254	Introduction to fuel technology laboratory	0	0	2	2

Course Objective
The main aim of the course is to give practical exposure of coal and other fuel characterization techniques and their significance.
Learning Outcomes
At the end of this course students should able to characterize fuel based on their properties and their significance during utilization.

Exp. No.	Name of Experiment	Practical Hours	Learning Outcome
1	Ultimate Analysis of coal.	2	Elemental analysis of coal
2	Proximate analysis of thermal coal	2	Determination of ash, moisture, volatile matter and fixed carbon contentsin coal
3	Free Swelling Index of coal	2	Swelling characteristics of coal
4	Caking index of coal	2	Caking and binding properties of coal

5	LTGK of coal	2	Coking properties of coal at low temperature
6	GCV of fuel	2	Heating values of fuel
7	Comparative proximate analysis of coal and coke	2	Property changes during carbonisation
8	HGI of coal	2	Grindability of coal
9	Characterisation of liquid fuels -I	2	Measurement of cloud point, pour point, smoke point, flash point and fire point of liquid fuels
10	Characterisation of liquid fuels -II	2	

COAL AND MINERAL PROCESS EQUIPMENT SELECTION

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	FMC301	Coal and mineral process equipment selection	3	0	2	11

Course Objective
The objective of the course is make students capable of selecting right equipment through worked out examples.
Learning Outcomes
Upon successful completion of this course, students will: • be made familiar with various fundamentals and guidelines for equipment selection • be able to do the selection and sizing of coal and mineral processing equipment for size reduction, separation and quality upgradation • be made familiar with costing and performance evaluation of the process equipment

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1	**Introduction**: various methodologies involved in selection and sizing of various coal preparation and mineral processing equipment	2	Students will learn about various methodologies for selection and sizing of processing units
2	**Equipment capacities**: Definitions of equipment capacities: Broad guidelines for equipment specifications required in tendering processes in coal preparation and mineral processing, **Equipment symbols**: Standard Process equipment symbols as per BIS norms.	2	Fundamentals of equipment, capacities and flowsheets along with costing and purchase
3	**Crushers:** Selection and sizing of reciprocating and non-reciprocating crushers, such as roll crushers and impact group of crushers for coal application and reciprocating crushers, such as jaw, gyratory and cone crushers for ore application Selection of rotary breaker for application in coal preparation	6	Selection and sizing of various size reduction units including primary, secondary and tertiary crushers through data based problem solving
4	Selection and sizing of rod, SAG and ball mills including re-grinding mills for metallic and non-metallic ores	5	Selection and sizing of various dry and wet grinding units through data based problem solving
5	Selection and sizing of industrial screens used in coal preparation and mineral processing Selection and sizing of hydrocyclones including limitations involved; General overview of selection criteria for mechanical classifiers	5	Selection and sizing of various size separation units including industrial screens, mechanical and hydrocyclones through data based problem solving
6	Application of probable error in separation, imperfection, organic efficiency NGM, cut-density, capacity, feed size,	4	Estimation and application of various technical and economic

	OPEX, CAPEX, yield reduction factor etc. (as applicable) in selection of density separators.		parameters in selection of density separators
7	Capacity estimation and selection of density separators used in metallurgical and thermal coal preparation including specific numerical examples as class work and as home work; Choice between Jigs, Dense Media Baths, Drums and Cyclones; Application of spirals and WOC.	7	Selection and capacity estimation of density separators for coal. Learning the rationale to make right choice of density separator.
8	Selection of different types of froth floatation cells (mechanical, Jameson, column, pneumatic, etc.) Estimation of number of banks and cells per bank for flotation of coal and minerals, such as limestone, fluorspar, copper and lead – zinc ores, etc with specific numerical examples as class work and as home work	4	Learn about selection of flotation cell and estimation of banks and cells per bank for various ores and minerals with the help of problems
9	General overview of selection criteria for magnetic and electrostatic separators	2	Learn about selection of magnetic and electrical separators
10	Performance Guarantee Tests for equipment used in coal preparation and mineral processing plants.	2	Learn about PGTsignificance and its application in processing plants

Text Books:

S. No.	Resource/Book Name	Author(s)/Editor(s)	Publisher
1	Mineral Processing Plant Design	Andrew L. Mular, Roshan Boman Bhappu	Society of Mining Engineers (AIME)
2	Mineral Processing Design and Operation: An Introduction	A. Gupta and D.S. Yan	Elsevier

Reference Books:

S. No.	Resource/Book Name	Author(s)/Editor(s)	Publisher
1	Process Selection in Extractive Metallurgy	Peter C. Hayes	Hayes Publishing
2	Mineral Processing Plant Design, Practice, and Control: Proceedings. Volumes I & II.	Andrew L. Mular, Doug N. Halbe, Derek John Barratt	Society for Mining, Metallurgy and Exploration

EXTRACTIVE METALLURGY

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	FMC302	Extractive Metallurgy	3	0	0	9

Course Objective
Introduction to unit operations used in the pyro/hydro-metallurgical extraction of metals from ore concentrates
Learning Outcomes
• Typical flowsheets in pyro/hydro-metallurgical metal extraction route. • Unit operations used in preliminary pyroprocessing and pyro/hydro-metallurgical processing of ore concentrates for extraction and purification of metals. • Typical flowsheets of some important non-ferrous metals.

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1	Typical ore to metal flow sheet; brief introduction to pyro/hydro-metallurgy, criteria for selecting	1	Introduction and definition of pyrometallurgy and hydrometallurgy

	pyrometallurgy/hydrometallurgy route for metal extraction		
2	Drying. Gas-solid reactions;shrinking core model; calcination, roasting, agglomeration,reduction reactions	8	Preliminary pyroprocessing of concentrate for subsequent pyro/hydro metallurgy unit operations
3	Smelting; matte smelting; flash smelting; converting; vacuum/inert-gas degassing; zone refining; fractional distillation;blast furnace, different zones in blast furnace, blast furnace profile	15	Fundamentals of pyrometallurgy and unit operations used for the extraction and refining of metals from concentrate
4	Leaching; types of leaching, Eh-pH diagrams and their usefulness, chemical precipitation; cementation, solvent extraction; ion exchange; aqueous and molten salt electrowinning; electrorefining; gaseous reduction of metals	12	Fundamentals of hydrometallurgy and unit operations used for recovery of metals from aqueous solution and molten salts
5	Typical flowsheets for extraction of metals such as copper, aluminium, magnesium	3	Examples of flowsheets for the extraction of important metals

Text Books:

S. No.	Resource/Book Name	Author(s)/Editor(s)	Publisher
1	Process Selection in Extractive Metallurgy	Peter C. Hayes	Hayes Publishing
2	Extraction of Nonferrous Metals	H. S. Ray, R. Sridhar, K. P. Abraham	Affiliated East-West Press
3	First Course in Iron and Steel Making	Dipak Mazumdar	Universities Press
4	Unit Operations of Chemical Engineering	Warren L. McCabe, Julian C. Smith, Peter Harriott	McGraw Hill

EXTRACTIVE METALLURGY LABORATORY

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	FMC351	Extractive Metallurgy laboratory	0	0	3	3

Course Objective
The objective of the course is to provide the practical knowledge forextraction of metals from its ores.
LearningOutcomes
Upon successful completion of this course, students will: • Able to prepare raw materials for pyro metallurgical process • Able to extract metal from lean ore through hydrometallurgy route

Exp. No.	Name of experiment	Contact Hours	Learning Outcome
1	Effect of moisture content on the size and drop strength of green iron ore pellets with fixed binder and angle of inclination in a disc pelletizer and drum pelletizer.	3	Understanding the effect of operation parameters of disc and drum pelletizers
2	Effect of binder content on the size and drop strength of iron ore pellet made with fixed moisture addition and angle of inclination in a disc pelletizer and drum	3	Effect of binders on properties of pellets

	pelletizer.		
3	Effect of disc/drum speed on drop strength of green iron ore pellets with fixed binder, moisture content and angle of inclination in a disc pelletizer and drum pelletizer.	3	Effect of design/operational parameter on properties of pellets
4	Effect of time on leaching of copper sulphide ore, lead sulphide ore and zinc sulphide ore in sulphuric acid media	3	Understand the effect and importance of leaching time
5	Effect of temperature on leaching of copper sulphide ore, lead sulphide ore and zinc sulphide ore in sulphuric acid media	3	Understand the effect and importance oftemperature for leaching
6	Effect of particle size on leaching of copper sulphide ore, lead sulphide ore and zinc sulphide ore in sulphuric acid media	3	Understand the effect and importance of particle size for leaching
7	Effect of leaching media on ore dissolution at fixed time, temperature and particle size	3	Effect and selection of leaching media
8	Study the kinetics of roasting of ZnS by weight loss method	3	Roasting of sulphide ore
9	Study the rates of oxidation of Cu and mild steel in atmospheric air by the weight gain method	3	Kinetics of oxidation of copper
10	Determination of decomposition voltage of aqueous solutions of $ZnSO_4$ Determination of current efficiency by using aqueous solution of $CuSO_4$.	3	Electrolysis of aqueous solution

MECHANICAL METALLURGY

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	FMC303	Mechanical metallurgy	3	0	0	9

Course Objective
Fundamentals of deformation of materials in response to applied forces and introduction to metalworking operations
Learning Outcomes
• Fundamentals of elastic and plastic deformation. • Strengthening mechanisms in metals. • Failure mechanisms in metals. • Introduction to fracture mechanics. • Fundamentals and methods of metalworking.

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1	Introduction and Elastic constants (atomistic origin), State of stress in 2D/3D, Transformation of stress, Principal stresses, Mohr Circle, Stress-strain relationships in isotropic and anisotropic materials	3	Stress-strain relationships for elastic behaviour
2	Tensile test; engineering and true stress-strain curves; ultimate tensile strength; toughness; ductile versus brittle	4	Introduction to the theory of plastic deformation

	behavior; strain measurement; effect of strain rates; Von Mises and Tresca yield criteria for ductile materials		
3	Concept of Dislocations, Dislocations in the lattice, Burger Vector and its properties, Stress and Strain fields of Dislocations, Energy of Dislocations, Forces on dislocation, Motion of Dislocations, Concept of slip systems, Single crystal slip (critical resolved shear stress - CRSS)	4	Understanding plastic deformation by dislocations
4	Strain hardening, Solid Solution Strengthening, Precipitation and Dispersion Strengthening, Grain Boundary and Hall-Petch relation	4	Strengthening mechanisms in metals
5	Introduction to fracture mechanics, Stress concentration, Crack growth criteria (Griffith, Irwin), Mode of deformation, Stress intensity factor, Fracture toughness, Classification of fracture and mechanisms	4	Fundamentals, characterization, and mechanisms of fracture
6	Introduction to Fatigue, Few cases of fatigue failures, SN curve, High and low cycle fatigue, Representation of fatigue data, Fatigue crack propagation, Mechanisms of fatigue fracture	4	Failure of metals by fatigue
7	Creep: Testing, Mechanisms: Diffusional related, Dislocations related, Grain boundary sliding, Harper Dorn, Power Law, Deformation Mechanism Maps	2	Time-dependent deformation of metals at high temperatures
8	Hardness Tests (Brinell, Rockwell, Vickers, knoop), Nanoindentation, Impact Testing	2	Methods for measuring mechanical properties
9	Classification of forming processes; mechanics of metalworking; Ideal work calculation; effect of temperature and strain rates, friction and lubrication; formability; forming limit diagram	4	Fundamentals of metalworking
10	Rolling; forging; extrusion; wire drawing; sheet metal working	8	Introduction to metalworking operations.

Text Books:

S. No.	Resource/Book Name	Author(s)/Editor(s)	Publisher
1	Mechanical Metallurgy	George E. Dieter	McGraw Hill

COAL AND MINERAL PROCESSING PLANT DESIGN

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	FMC304	Coal and mineral processing plant design	3	0	2	11

Course Objective
To give overall idea of coal and mineral processing plant design.
Learning Outcomes
Upon successful completion of this course, students will get project-based experiential learning of coal and mineral processing plant design, which includes flowsheet preparation, materials handlingand utility systems selection, contracts and project management and economics using software tools.

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1	**Introduction –** BIS guidelines on flowsheet definitions and symbols,Basic data required for plant flowsheet design. Plant capacity estimation, techno-economic feasibility calculations. Basic calculations like mass, water, grade,	6	This unit will give students the general background of plant design along with technical and environmental aspects.

	energy balance. Environmental impact assessment during plant design.		
2	**Mineral process plant flowsheets -** Development of plant flowsheets for mineral processing plants including iron, sulphide ore, mass, water and grade balancing.	8	Understanding of flows sheet design of mineral processing plants
3	**Coal preparation plant flowsheets -** Development of plant flowsheets for thermal and metallurgical coals on single and composite (blended) feed basis including mass, water and ash balancing.	7	Understanding of flows sheet design of coal preparation plants
4	**Other plant flowsheets -** Flowsheet development for beach sand, rock phosphate, limestone, graphite, uranium ore etc.	4	Understanding of flows sheet design of strategic, nuclear, industrial minerals, etc.
5	**Material handling and utility system:** General guidelines on solid and liquid storage and transportation (belt conveyor and pumps). Selection and sizing of belt conveyors and pumps. Guidelines on selection of valves, pipes, bends, blower, compressor, cooling tower.	7	This will help students to understand the handling of solid, water and slurry along with utilities used in plants.
6	**Contracts and Project Management** - Introduction to NIT (Notice Inviting Tender), technical and commercial contract. Steps of project award, Project costing, Basic and detail engineering, Purchase of equipment, Plant erection and commissioning, Performance Guarantee Test. Mechanical, civil, structural, instrumentation, electrical aspects in plant design. Plant optimization and profitability calculations	5	Students shall be able to get the idea handling contract, procurement, project costing, etc.
7	**Engineering economics:** Capital cost, operating cost, depreciation, return on investment	2	Knowledge related to economics of engineering
8	**Operational aspects of plant design** - Project on plant design, development of process flow sheet using MS Excel and ASPEN. Selection of equipment, mass/water/grade balancing, report submission.	(26)	This is practical work done by groups of students starting from material characterization to equipment selection, development of flowsheet, costing, etc.

Text Books:

S. No.	Resource/Book Name	Author(s)/Editor(s)	Publisher
1	Mineral Processing Plant Design	Andrew L. Mular, Roshan Boman Bhappu	Society of Mining Engineers (AIME)
2	Mineral Processing Design and Operation: An Introduction	A. Gupta and D.S. Yan	Elsevier

Reference Books:

S. No.	Resource/Book Name	Author(s)/Editor(s)	Publisher
1	Introduction to Mineral Processing	Errol G. Kelly, David J. Spottiswood	John Wiley and Sons

HEAT TREATMENT AND MECHANICAL METALLURGY LABORATORY

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	FMD 353	Heat Treatment and Mechanical Metallurgy laboratory	0	0	3	3

Course Objective
The objective of the course is to understand correlation of equilibrium diagram, heat treatment, microstructure and mechanical properties of materials.

LearningOutcomes
Upon successful completion of this course, students will be able to draw heat treatment cycles and predict resultant microstructure and mechanical properties of steels and non-ferrous metals

Exp No.	Name of the experiment	Contact Hours	Learning Outcome
1	Preparation of specimens for microscopic examination – steels, copper alloys and aluminium alloys; hot mounting and cold mounting and mechanical fixtures.	3	Understanding of basic process for sample preparation
2	Microstructural study by etching of specimens of steel, copper alloys and aluminium alloys and cast iron.	3	Understanding of fundamentals of etching and microstructure
3	Quantitative Metallography for phase volume fraction by point counting and linear intercept method	3	This will help in quantifying volume fraction by different methods
4	Estimation of phases and drawing of cooling curves for transformation of plain carbon steels with varying carbon contents using Fe-C diagram. Observation and description of microstructures of annealed plain carbon steels.	3	Fundamental of Fe-C equilibrium phase diagram
5	Performing annealing, normalizing and hardening heat treatment of steel samples; observation of microstructures and hardness.	3	Understand the process of heat treatment
6	Hardenability determination by Jominy End Quench test as per ASTM standard; estimation of hardenability using composition of steel.	3	Understand the process of hardenability determination
7	Design of isothermal heat treatment cycle using TTT/CCT diagram using fluidized bed and salt bath furnace.	3	This will help in designing isothermal heat treatment cycle
8	Performing surface heat treatments like carburizing, nitriding on steels; estimating resultant case depth.	3	Practical understanding of heat treatment and hardenability
9	Observation and description of microstructure of typical alloy steels such as micro-alloyed steel, dual phase steel, free cutting steel, bearing steel and maraging steel.	3	Fundamental of microstructure and property correlation
10	Determination of the tensile properties of different class of materials	3	Understanding of tensile property of materials
11	To study the strain aging behavior of steel (associated with the yield-point phenomena) using load-elongation curve obtained from tensile test	3	Stain aging and yield point phenomenon
12	To interpret ductile-brittle behavior of mild steel at various temperature from the absorbed energy (indication of toughness) during impact	3	Impact testing of materials (Charpy Impact Test)
13	To study the constant load creep behavior of Aluminium	3	Understanding of Creep property of materials
14	To measure and compare the Brinell, Rockwell and Vickers hardness of mild steel, aluminum and brass	3	Principle of hardness testing and comparison of different hardness measurement techniques
15	To study the effect of cyclic loading normally encountered by the materials in service	3	Fatigue Testing
16	To study the effect of cold rolling on the tensile properties of aluminium	3	Effect of work hardening on the tensile properties of metals

COMPUTATIONAL TECHNIQUES AND MODELLING

Course Type	Course Code	Name of Course	L	T	P	Credit
DE	FME461	Computational techniques and modelling	3	0	0	9

Course Objective

The objective of the course is to make the students aware of different approaches to be adopted for metallurgical accounting and computation of operational performances of Mineral processing plants and to know about the mathematical tools to be adopted for developing models for different operations/equipment and their application

Learning Outcomes

Upon successful completion of this course, students will

- have a broad understanding of the approaches for carrying out material balancing of solid, water and slurries in two product separation systems.
- the subject will give an insight on to the operating performances of size separation and beneficiation units
- upon learning, the student will become conversant with minimization of errors involved in estimation of product yield and component recoveries after processing.
- the subject will also make the students to become familiar of the different the optimization techniques to be adopted in operating plants.

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1	Introduction, types of computations and methodologies.Reconciliation of excess data for minimization of errors involved in yield and recovery calculations	5	Introduction to material balancing and other calculations
2	Mass balancing of complex beneficiation circuits, concept of connection matrix its main applications including component balancing; its uses and advantages, with examples from Pb-Zn, iron ore, coal and beach sands	5	Difficulties faced in mass balancing of complex circuits and the constraints faced in operating plants besides making them to compute minimum number of streams to be sampled to perform mass balancing.
3	Reconciliation of excess data for minimization of errors involved in yield and recovery calculations.	5	Helps to understand how to optimize product yield and recoveries,
4	Statistically aided computation of errors involved in size and chemical analysis of feed and product streams for estimation of accurate yield in the plant operations Application of Lagrangian Multipliers to correct errors in assay values feed, concentrate and tailing streams	6	This will help student in estimating the extent of uncertainties and ranges in which the fluctuation can takes place in the data analysis and knowledge of the corrections can be made assay values of the components considered
5	Introduction to mathematical modelling, Types of models, their relative merits and demerits. Description on empirical and semi empirical models.	4	This will help in understanding of different techniques to be adopted for development of mathematical models in processing coal and mineral processing.
6	Modelling of size reduction processes, use of Matrix modelling for crushers and application of kinetic models and grinding mills. Description and application of Breakage, Selection Function and classification functions, numerical examples for computing product distribution using different models. Mathematical models for different processing equipment and for partition curves	4	This unit will help the student the approach of adoption of matrix modelling for comminution units considering size distribution information of feed and products and the extent breakage took place during comminution.

7	Modelling of Flotation operations for batch and continuous flotation. Kinetic approaches, different kinetic models, estimation of order of equation. Scale-up models for continuous flotation using mechanical cells. Use of kinetic models for design of flotation circuits.	5	Helps to understand the kinetic behavior of the process and through kinetics rate of flotability and based on flotability the size of flotation circuit and size of the cell required.,
8	Population balance models; Discrete Element Modelling	5	Familiarisation with population balance modelling and discrete element modelling

Text Books:

S. No.	Resource/Book Name	Author(s)/Editor(s)	Publisher
1	Modeling and Simulation of Mineral Processing Systems	R. P. King	Butterworth-Heinemann

Reference Books:

S. No.	Resource/Book Name	Author(s)/Editor(s)	Publisher
1	Introduction to Mineral Processing	Errol G. Kelly, David J. Spottiswood	John Wiley and Sons
2	Wills' Mineral Processing Technology	Barry A. Wills James Finch	Society for Mining, Metallurgy and Exploration
3	Principles of Mineral Dressing	Antoine Marc Gaudin	McGraw Hill

PROCESS CONTROL AND PLANT LAYOUT

Course Type	Course Code	Name of Course	L	T	P	Credit
DE	FMC462	Process control and plant layout	3	0	0	9

Course Objective
To give concept of various control instruments, process control and plant layout
Learning Outcomes
Upon successful completion of this course, students will understand: • control instruments, control strategy adopted • equipment control, plant control operations and plant layout design

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1	**Introduction:** Need of process control, technical and economic benefits. Fundamental Aspects-Recognition of dynamic nature of control operation; identification of controllable and non-controllable operating variables; defining control objectives; identification of process and plant constraints.	5	Understanding of basic understanding of various mineral processes and process control.
2	**Types of Control Actions:** Feed Forward and feedback control; construction of a feedback controller; proportional action, integral action and derivative action; tuning of feedback controllers; multiple input control; ratio control and cascade control.	5	This unit will help student in understanding the various control actions.
3	**Instrumentation for measurement:** On-line particle size distribution, Metallurgical grade analysis and coal analysis; pulp density, pulp level, froth level, slurry flow rate, ball mill load, pressure, temperature and other required measurements.	8	This will help students in understanding different instruments used in controlling mineral processing plants.
4	**Control of plant operations:** Crushing circuit, grinding circuit, flotation circuit, jig circuit and DMC circuit, dewatering and other	15	This will enable students to select and define

	allied operations. PLC and DCS control systems. Expert systems for plant control. Example of some actual implementation of control systems in an operating plant and the control strategies used.		control strategy for a plant.
5	**Plant Layout:** Introduction of Plot Plan, Contour, Concept of levels, Floors, Location of equipment, etc. Design of Plant layout, Building Layout, Equipment Layout. Input details required to design a plant layout. Major points considered while designing a plant layout. Layout design of plant buildings - crushing, grinding, flotation, dewatering, etc. Introduction to piping layout. Role of civil and structural inputs in layout design.	6	This will help students to understand the design of equipment, building and plant layout.

Text Books:

S. No.	Resource/Book Name	Author(s)/Editor(s)	Publisher
1	Mineral Processing Plant Design, Practice, and Control: Proceedings. Volumes I & II.	Andrew L. Mular, Doug N. Halbe, Derek John Barratt	Society for Mining, Metallurgy and Exploration
2	Mineral Processing Design and Operation: An Introduction	A. Gupta and D.S. Yan	Elsevier

Reference Books:

S. No.	Resource/Book Name	Author(s)/Editor(s)	Publisher
1	SME Mineral Processing and Extractive Metallurgy Handbook	Robert C. Dunne, S. Komar Kawatra, Courtney A. Young	Society for Mining, Metallurgy and Exploration
2	Introduction to Mineral Processing	Errol G. Kelly, David J. Spottiswood	John Wiley and Sons
3	Wills' Mineral Processing Technology	Barry A. Wills James Finch	Butterworth-Heinemann

NON-FERROUS EXTRACTIVE METALLURGY

Course Type	Course Code	Name of Course	L	T	P	Credit
DE	FMD463	Non-ferrous Extractive Metallurgy	3	0	0	9

Course Objective
The objective of the course is to provide the knowledge of extraction of non-ferrous metals from its ores.
LearningOutcomes
Upon successful completion of this course, students will: • have a broad understanding of principles of extraction of metals. • have a high-level understanding of process variables to enhance the productivity and efficiency of different processes. • be able to understand basic flowsheet of non-ferrous metal extraction.

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1	Brief Introduction to Principles of metals extraction processes.	2	To recollects the basics.
2	Introduction to extraction of non-ferrous metals, their sources. General methods used for the extraction metals from sulphides, oxides, hydroxides, native metals etc.	2	This will help the students to understand the various methods/ routes and sources

			used in the extraction processes
3	Extraction of metals from hydroxide/oxide minerals: Extraction of Aluminium, Bayer's process for the production of alumina and its under lying principles. Fused salt electrolysis, factors affecting fused salt electrolysis Hall-Heroult process, role of cryolite and mechanism involved in the process. Newer Process for Aluminium production (ALCOA Process). Extraction of Tin, smelting and refining of tin concentrate. Extraction magnesium (PIDGEON and DOW Process), with reaction mechanisms involved in the processes.	8	Students will gain the knowledge of production of typical metals from hydroxides/oxide by different methods.
4	Extraction of metals from sulphides: Extraction of copper by conventional (roasting, smelting and converting) process. Newer processes for copper extraction such as Flash smelting, WORCRA and NORANDA processes. Extraction of lead. Refining of lead bullion, Parke's desilverization. Modern development in lead smelting. Extraction of zinc, different methods involved in the process, Imperial Smelting Process, Condensation of zinc vapours, Roast leach electrolytic process. Extraction of nickel by pyrometallurgical process, hydrometallurgy of nickel sulphides concentrate.	10	This will enable the students to understand extraction of base metals from their sulphides.
5	Extraction of Nuclear Metals. Hydrometallurgical Extraction of uranium by acid and alkali leaching. Extraction of Titanium. Smelting of Ilmenite, Sorel Process. Production of Ti sponge by KROLLs Process. Extraction of rare earth metals	8	This portion will help in knowing the extraction of nuclear metal and rare earth metals.
6	Production of precious metals. Extraction of gold and silver by cyanidation process and their under lying principles. Recovery gold by reductive precipitation, CIP and CLL processes. Extraction of platinum group of metals.	4	Provides necessary fundamental and application of extraction of precious metal from its native ores.
7	By-product recovery from waste, such as red mud,and utilization.	3	This will help knowing the utilization of by-products.
8	Flow sheets and general methods of refining, (Drossing, Fractional distillation, Zone and fire refining.)	2	This will enable the students to the flow sheets and brush-up refining techniques.

Text Books:

S. No.	Resource/Book Name	Author(s)/Editor(s)	Publisher
1	Extraction of Nonferrous Metals	H. S. Ray, R. Sridhar, K. P. Abraham	Affiliated East-West Press
2	Principles of Extractive Metallurgy	H.S. Ray, A. Ghosh	New Age International
3	Hydrometallurgy	S. Venkatachalam	Narosa Publication
4	Hydrometallurgical Extraction and Reclamation	Eric Jackson	Ellis Horwood

Reference Books:

S. No.	Resource/Book Name	Author(s)/Editor(s)	Publisher
1	Extractive Metallurgy	W.H. Dennis	Pitman Publishing

2	Principles of Extractive Metallurgy, Volume 1	Fathi Habashi	CRC Press
3	Principles of Extractive Metallurgy	Terkel Rosenqvist	Tapir Academic Press
4	Non-Ferrous Production Metallurgy	J. L.Bray	John Wiley and Sons
5	Unit Processes of Extractive Metallurgy	Robert D. Pehlke	Elsevier
6	Introduction to Melts: Molten Salts, Slags and Glasses	H. S. Ray	Allied Publishers
7	Energy In Minerals & Metallurgical Industries	H. S. Ray, B. P. Singh, Sarama Bhattacharjee, Vibhuti N. Misra	Allied Publishers

MINERAL POLICY AND ECONOMICS

Course Type	Course Code	Name of Course	L	T	P	Credit
DE	FMD464	Mineral policy and economics	3	0	0	9

Course Objective
To give concept of overall economics of coal and mineral processing plants
Learning Outcomes
Upon successful completion of this course, students will: • be able to understand Indian and global scenario of mineral processing activities • be able to understand plant economics that will help in designing the plant. • be able to understand the possible future technology.

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1	**Global scenario:** World reserves of important minerals. Different reserves classification systems e.g. UNFC, JORC. India's position in global mineral industry. Depletion of mineral resources and beneficiation prospects.Future potential of key minerals and factors driving their demand	6	Understanding of National and global scenario of mineral reserves and key driving factors for their technology.
2	Metal prices and markets. Production, consumption and prices of minerals. Market structure of selected minerals.	3	Understanding of mineral markets
3	**Indian Mineral Industry:** • Mineral reserves in India and classification system adopted • Contribution of minerals to Indian industrial and economic growth. • Roles & responsibility of key government organisations managing the mineral sector: Policy framework in India • Domestic Demand and supply scenario of key minerals and metals. • Future scenario and steps required to meet future requirements	5	This unit will help student in understanding the government rules, environmental limitations and other related aspects affecting the mineral processing in India.
4	**Economics of mineral projects:** • Typical cost components in a mineral project: Capital costs, operating costs (fixed and variable costs)	10	This will help students in understanding economic aspects of plant design and operation.

	• Key financial aspects to evaluate feasibility of project - cost curve, profitability, Net Present Value, IRR and depreciation accounting		
5	**Social and environmental assessment:** Aspects for sustainable development of mineral industry: environment, social, resource conservation, communityhealth, Life cycle assessment, environmental audit, R-R-R approach for sustainability etc.	8	This will enable students to understand social and environmental aspects of plant design and operation.
6	Future technologies for sustainable processing of coal, minerals and metal recovery	7	This will help students to understand the future technologies.

Text Books:

S. No.	Resource/Book Name	Author(s)/Editor(s)	Publisher
1	An Introduction to Mineral Economics	K. K. Chatterjee	New Age International

Reference Books:

S. No.	Resource/Book Name	Author(s)/Editor(s)	Publisher
1	Mine and Mineral Economics	Subhash C. Ray, Indra N. Sinha	Prentice Hall
2	Ore Geology, Economic Minerals and Mineral Economics	S. K. Tiwari	Atlantic Publishers

IRON AND STEEL MAKING

Course Type	Course Code	Name of Course	L	T	P	Credit
DE	FMD525	Iron and Steel Making	3	0	0	9

Course Objective
The objective of the course is to provide the knowledge of iron making through blast furnace route as well as alternative routes, basic knowledge of steel making, secondary steel making and continuous casting.
Learning Outcomes
Upon successful completion of this course, students will: • have a broad understanding of iron making and steel making. • have a high-level understanding of process variables to enhance the productivity and efficiency blast furnace and alternative routes of iron making. • be able to understand basic layout of blast furnace, steel making shop and continuous casting process. • beable to control the cost of the steel by careful selection of the raw materials and other necessary ingredients required for steel manufacturing.

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1	Raw-Materials: Iron ore quality w.r.t. size, chemistry and other properties, Types of fluxes used and the importance of coke-quality for iron making. Requirement of Raw-materials per tonne of Liquid Iron Production.	5	Understanding of iron making, quality and quantity of raw materials required for the production per tonne of hot metal.
2	Agglomeration of Iron ore fines, Sintering; Principles, sintering bonds, sintering machines; Pelletisation; Theory of Pelletisation, Water-particles system. Production of green pellets in; disk and drum pelletizers, Induration of pellets, Shaft, traveling grate and continues grate kiln machine.	5	Understanding of iron bearing raw materials preparation for blast furnace feed especially when high grade ore is not availaboratoryle.

3	Overview of Blast furnace, six internal zones of blast furnace, Blast furnace operation – Thermodynamic principles, refractories, temperature profile, aerodynamics, high top pressure, different factors, irregularities etc.	6	Understanding of overview of the furnace, basic principles and problems occurs during operation of blast furnace.
4	Blast furnace reactions, thermodynamics of slag-metal reactions, oxygen enrichment, injection of steam, Blast furnace products - pig iron, top gas, slag & their utilization, cleaning of off gas, Blast furnace design & sizing, productivity, coke rate etc.	7	This will help is designing the blast furnace, reaction model and utilization by-products.
5	Introduction to alternative iron making processes: Principles of Sponge Iron Making, Degree of Metallization, Percentage Reduction direct reduction process – DRI, HBI, Principles & technology of different coal based & gas based direct reduction processes like Rotary kiln, Rotary hearth, Midrex, HyLetc Smelting Reduction Processes such as COREX, ROMELT, HiSmelt, Finexetc	6	This unit will help student in understanding the alternative route for iron making.
6	Steel making: Principles of steel making, Different methods used such as L.D. Converter and Electric Furnaces. De-oxidization of steel, uses of different types of de-oxidizers and alloys for different purposes.	6	This will help student in refining of hot metal and production steel.
7	Secondary steel making, stainless steel making, Continuous casting etc.	4	Understanding of further refining of steel and giving a shape.

Text Books:

S. No.	Resource/Book Name	Author(s)/Editor(s)	Publisher
1	First Course in Iron and Steel Making	Dipak Mazumdar	Universities Press
2	Iron Making and Steelmaking: Theory and Practice	Ahindra Ghosh, Amit Chatterjee	Prentice Hall
3	Principles of Blast Furnace Ironmaking	A.K. Biswas	SBA Publications
4	Fundamentals of Steelmaking Metallurgy	Brahma Deo, Rob Boom	Prentice Hall
5	Fundamentals of Steelmaking	E.T. Turkdogan	Maney Publishing
6	Physical Chemistry of Melts in Metallurgy	F.D. Richardson	Academic Press

Reference Books:

S. No.	Resource/Book Name	Author(s)/Editor(s)	Publisher
1	An Introduction to Modern Steel Making	R.H. Tupkary, V.R. Tupkary	Khanna Publishers
2	Extraction Metallurgy	J. D. Gilchrist	Pergamon Press
3	An Introduction to Modern Iron Making	R.H. Tupkary, V.R. Tupkary	Khanna Publishers

CEMENT TECHNOLOGY

Course Type	Course Code	Name of Course	L	T	P	Credit
DE	FMD526	Cement technology	3	0	0	9

Course Objective
The aim of this course is to provide fundamental knowledge about cement manufacturing processes and utilization of different types of fuels and raw materials in cement manufacturing.
Learning Outcomes
After attending the course students will be able to understand cement manufacturing process and role of various fuels in cement manufacturing.

1.

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1	Various processes of cement manufacture – dry, semi-dry and wet, overview of various unit operations. Indian cement industry, the global scenario.	4	Overview of cement manufacturing processes.
2	Phase composition of clinker minerals and cement, pozzolanic reaction, hydration of cement, Raw mix proportioning, 2-, 3- and 4-component mixes, concepts of burn ability, absorption and effect of coal ash Different zones in a cement kiln, preheaters and pre-calcinators.	15	Various reactions, raw materials and cement manufacturing methods.
3	Coolers, burners, fuels, waste-derived fuels, Pet coke, refractory and refractory practices.	8	Various equipment and their design aspects for cement manufacturing.
4	Testing of cements for various properties	4	Testing of cements.
5	Approaches to energy conservation, energy audits, co-generation of power, Pollution control, noise abatement, concepts of LCA. EIA and EMP.	4	Various energy conservations methodologies in cement plant.
6	Quality control and plant layout of modern cement plants.	4	Students will know various quality control methods in cement plant and plant layout.

Text Books:

S. No.	Resource/Book Name	Author(s)/Editor(s)	Publisher
1	The Chemistry of Cement and Concrete	F. M. Lea	Chemical Publishing Company

Reference Books:

S. No.	Resource/Book Name	Author(s)/Editor(s)	Publisher
1	Cement Data-book	W.H. Duda	Bauverlag GmbH
2	The Chemistry of Portland Cement	Robert Herman Bogue	Reinhold Publishing Corporation

WASTE PROCESSING AND MANAGEMENT

Course Type	Course Code	Name of Course	L	T	P	Credit
OE	FMO543	Waste processing and management	3	0	0	9

Course Objective
To give knowledge of waste generation from processing plants, characterization and utilization.
Learning Outcomes
Upon successful completion of this course, students will be able to get information of plant waste and its utilization in various industries.

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1	Waste generation from processing plants, handling, storage and environmental hazards.	4	Students will be able to identify the sources of waste materials and their hazardous effects on environments.
2	Characterization and utilization of solid wastes - red mud, steel plant waste, fly ash waste, coal tailings, etc.	4	Students will be able to characterize the waste

			materials to identify their utilization potentials.
3	Utilization of solid waste as building material, fertilizer, PVC products, paints, pigments, cement industries, brick making, coating, chemical industries, filtration, purification, etc.	10	Students will get knowledge about waste materials from various industries and ways to utilize them.
4	Composition and properties of slags from BF, LD, EAF, Cupola, Slag produced in Non-ferrous plants. Cements: type of slag, granulation treatment, transportation, grinding, mixing & properties. Slag Wool: Type of slag, granulation, handling, compaction. Slag Blast: properties & uses in Fertilizer industries, Composition, treatment & application, Slag grinding.	9	Students will get knowledge about waste materials from metallurgical industries and ways to utilize them.
5	Properties: Composition, size, shape, surface properties, refractoriness, density. Applications: Building Brick – Binder selection, mixing, compaction, strengthening, Testing, Equipments, economics. Insulation brick – Additives, compaction firing and testing. Soil treatment – characteristic properties, uses, Pozolana – Properties & testing Road Making – Properties & Testing, Horticultural Use, Effluent Treatment, Mine filling, Smelting, Other uses.	12	Students will get knowledge about products generated from waste materials of various industries.

Text Books:

S. No.	Resource/Book Name	Author(s)/Editor(s)	Publisher
1	Wealth From Waste: Agricultural, Food And Chemical Processing Waste (Vol. 1)	S. C. Bhatia	Atlantic Publishers

Reference Books:

S. No.	Resource/Book Name	Author(s)/Editor(s)	Publisher
1	Environmental Engineering	Howard Peavy, Donald Rowe, George Tchobanoglous	McGraw Hill

CLEAN COAL TECHNOLOGY

Course Type	Course Code	Name of Course	L	T	P	Credit
DE	FMO544	Clean coal technology	3	0	0	9

Course Objective
The main aim of the course is to give fundamentals concept of efficient way of utilizing coal in different applications with minimum environmental impact.
Learning Outcomes
At the end of the course student will be able to identify various techniques of utilizing coal for cleaner environment.

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1	**Introduction to clean coal technology**: Coal quality parameters for utilization in thermal power plant, cement, steel and DRI plant. Pre-combustion cleaning, during combustion cleaning, post-combustion cleaning, burning time, unburned carbon estimation and control. Biological and chemical cleaning	10	Students will learn various methods of coal cleaning methods and their merits and demerits.

	methods.		
2	**Emission control:** Fly ash, SO_x and NO_x control strategies during combustion and after combustion. Use of ESP, Cyclones, Filters and settling chambers. CO_2 sequestration.	10	Students will learn various control strategies for pollution control from coal based industries.
3	**Coal gasification: G**asifying agents: oxygen, air, steam, reactions involved in gasification. Effect of fuel properties on product, blending of fuels. Syn gas, Fuel gas.	8	Students will learn various fundamentals of coal gasification technologies will
4	**Types of gasifiers**: Fixed bed, moving bed, fluidized bed, entrained bed etc. Product gas cleaning and energy utilization, removal of H_2S, NH_3, tar, suspended particulate matter.	5	Students will understand design and operation aspects of various types of gasifier.
5	**Other technologies:** Underground coal gasification (UCG), Coal bed methane, recovery of methane from CBM (Coal Bed Methane), CMM (Coal Mine Methane), AMM (Abandoned Mine Methane), combined cycle power generation (IGCC), oxy-fuel combustion.	6	Students will learn other utilization aspects of coal and coal based gases.

Text Books:

S. No.	Resource/Book Name	Author(s)/Editor(s)	Publisher
1	Clean Coal Engineering Technology	Bruce Miller	Butterworth-Heinemann

Reference Books:

S. No.	Resource/Book Name	Author(s)/Editor(s)	Publisher
1	Fuels and Combustion	Samir Sarkar	Universities Press
2	The Chemistry and Technology of Coal	James P. Speight	CRC Press

EQUIPMENT DESIGN

Course Type	Course Code	Name of Course	L	T	P	Credit
DE	FMO545	Equipment design	3	0	0	9

Course Objective
The main objective of the course is to learn the methods of design of equipment used in various energy related operations
Learning Outcomes
At the end of the course, student will be able to theoretically design equipment and improves the understanding about the equipment

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1	Introduction to equipment design. Process flow diagram, material and energy balance, material of construction, properties of materials, corrosion due to high temperature, corrosive atmosphere, abrasive material	6	Understanding of the prerequisites for equipment design
2	Design of cyclone separator, centrifuges, furnace, kiln, fluidized bed reactor, pulverized combustion units, silos, pressure vessel	8	Knowledge of the design methodologies for various equipment/vessels
3	Process design of shell and tube heat exchanger, condenser, cooling tower. Mechanical design of shell & tube heat exchanger	8	Knowledge of the design methodologies for different heat exchangers
4	**Design of tall vessels**: Introduction, Axial stresses due to	8	Knowledge of the design of tall

	dead loads, Axial stresses due to pressure, Longitudinal bending stresses due to dynamic loads, Design considerations of distillation (tall) and absorption column (tower)		vessels
5	**Process Hazards and Safety Measures in Equipment Design:** Process Hazards, Safety measures, Safety measures in equipment design, Pressure relief devices	9	Understanding of the hazards and safety measures to be considered during equipment design

Text Books:

S. No.	Resource/Book Name	Author(s)/Editor(s)	Publisher
1	Joshi's Process Equipment Design	V. V. Mahajani, S. B. Umarji	Trinity Press

Reference Books:

S. No.	Resource/Book Name	Author(s)/Editor(s)	Publisher
1	Process Equipment Design	S. D. Dawande	Denett and Company
2	Relevant Indian Standards	BIS	BIS

ELEMENTS OF MINERAL ENGINEERING

Course Type	Course Code	Name of Course	L	T	P	Credits
OE	FMO431	Elements of Mineral Engineering	3	0	0	9

Course Objective
To learn about the principles and practices of different mineral engineering operations, in brief
Learning Outcomes
Upon successful completion of this course, students will have a brief knowledge of • the fundamentals of mineral engineering • the comminution and classification techniques applied in mineral engineering • the concentration techniques used in mineral engineering • the various dewatering techniques applied for ores and coal • the methods of hydrometallurgical extraction • the flowsheets of different ores and coal

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcomes
1	**Introduction:** Scope, objectives and applications of mineral processing; Liberation and beneficiation characteristics of minerals and coal	4	Familiarisation with the basic introductory concepts of mineral engineering
2	**Comminution:** Theory and practice of crushing and grinding; Different types of crushing and grinding equipment, their application	6	Information about the fundamental different comminution principles and equipment
3	**Size separation:**Laboratory size analysis and interpretation; Settling of solids in fluids; Industrial screens; Mechanical classifiers and hydrocyclones	4	Information about the basics of different classification principles and equipment
4	**Density separation methods:** Jigging, dense medium separation Spirals and Wilfley tables: theory, application and limitations.	9	Introduction to the different density-based concentration technologies
5	**Froth flotation:** Physico-chemical principles; Reagents; Machines; Flotation of sulphides, oxides and coal.	6	Familiarisation with basics of froth flotation technology

6	**Electrical and magnetic methods of concentration:** Principles, fields of application and limitations.	4	Introduction to the electrical and magnetic methods of concentration
7	**Dewatering:** Thickening, filtration and drying.	4	Knowledge of the fundamentals of dewatering
8	**Typical flow sheets:**Coal, copper, lead-zinc, iron, beach sands, etc.	2	Familiarisation with the conceptual flowsheets of important ores and coal, employed in mineral engineering plants

Text Books:

S. No.	Resource/Book Name	Author(s)/Editor(s)	Publisher
1	Wills' Mineral Processing Technology	Barry A. Wills James Finch	Butterworth-Heinemann

Reference Books:

S. No.	Resource/Book Name	Author(s)/Editor(s)	Publisher
1	Principles of Mineral Dressing	Antoine Marc Gaudin	Tata McGraw Hill

CHARACTERIZATION OF MATERIALS

Course Type	Course Code	Name of Course	L	T	P	Credit
OE	FMO541	Characterization of materials	3	0	0	9

Course Objective
The objective of the course is to learn characterization of minerals and materials using various analytical instruments and data interpretation.
Learning Outcomes
Upon successful completion of this course, students will be able understand various characterization technologies for materials, analysis of results obtained from equipment and correlate them with the properties of materials.

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1	Introduction to material characterization, necessity of characterization, methods of analysis	4	Students will be able to understand the necessity of characterization of materials and ways to analyze them.
2	Materials characterization: importance and applications; principles of XRD, XRF.	4	Students will know various characterization techniques based on X Ray.
3	Microscopy techniques: optical and electrons (SEM, TEM, AFM) microscopy, QEMSCAN.	6	Students will know various characterization techniques based on microscopic analysis.
4	Introduction to spectroscopy (UV-vis, FTIR and Raman), HPLC.	4	Students will know various characterization techniques based on spectroscopy.
5	Thermal stability analysis: thermogravimetric analysis (TGA) and differential scanning calorimetry (DSC).	4	Students will know various thermal characterization techniques.
6	Mechanical property characterization: principles and characterization of tensile, compressive, hardness, fatigue, and fracture toughness properties.	4	Students will know various mechanical characterization techniques.
7	Principles of characterization of other materials properties: BET surface area; chemisorption; particle size; zeta potential; rheology; and interfacial tension, FTIR, GCMS, LCMS, Ion Meters etc.	13	Students will know various characterization techniques based on individual properties of materials.

Text Books:

S. No.	Resource/Book Name	Author(s)/Editor(s)	Publisher
1	Materials Characterization: Introduction to Microscopic and Spectroscopic Methods	Yang Leng	Wiley-VCH Verlag GmbH and Co.

Reference Books:

S. No.	Resource/Book Name	Author(s)/Editor(s)	Publisher
1	Surface Characterization Methods: Principles, Techniques, and Applications	Andrew J. Milling	CRC Press
2	Materials Science and Engineering: An Introduction	William D. Callister Jr., David G. Rethwisch	John Wiley and Sons