Final

DIPLOMA CURRICULUM OF METALLURGICAL ENGNEERING (SECOND YEAR) (4th Semester)

(To be implemented from 2025-26)

Prepared by;

National Institute of Technical Teachers’ Training & Research Kolkata
Block – FC, Sector – III, Salt Lake City, Kolkata – 700106

Vetted by:
Domain experts from Polytechnics of Odisha

State Council for Technical Education & Vocational Training
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SEMESTER – IV (METALLURGICAL ENGNEERING)

SL. No	Category of Course	Code No	Course Title	Pre-requisite	L	T	P	Theory End Exam	Theory Progressive Assessment	Practical End Exam	Practical Progressive Assessment	Total Marks	Credits
1	**Programme Core**	MTPC202 TH:1	Iron making		3	0	0	70	30	-	-	100	3
2		MTPC204 TH:2	Physical metallurgy		3	0	0	70	30	-	-	100	3
3		MTPC206 TH:3	Industrial metallurgy		3	0	0	70	30	-	-	100	3
4		MTPC208 PR:1	Industrial metallurgy lab		0	0	4			15	35	50	2
5		MTPC210 PR:2	Modelling & Simulation lab		0	0	4			15	35	50	2
6		MTPC212 PR:3	Material characterization lab		0	0	4			15	35	50	2
7	**Programme Elective**	MTPE202 (Any one) TH:4	(A) Material Characterization (B) Functional Material (C) Phase Transformations		3	0	0	70	30	-	-	100	3
8		MTPE204 (Any one) TH:5	a) Non-ferrous Extractive Metallurgy (B) Non-Metallic Material (C) Energy Material		3	0	0	70	30	-	-	100	3
10	**Minor Project**	PR202 PR:4	MINOR PROJECT		0	0	4	-	-	30	70	100	2
11	**Mandatory**	AU202	Essence of Indian knowledge and tradition		2	0	0	-	-	0	0	0	0
TOTAL					**17**	**0**	**16**	**350**	**150**	**75**	**175**	**750**	**23**

The best of 2 IA conducted in a subject out of 20 marks to be considered. Assignment/ quiz etc. of 10 marks to be treated as part of IA. Besides this, Monthly Test to be conducted for each subject. Sessional Marks shall be total of the performance of individual different jobs/ experiments in a subject throughout the semester. Club/Innovation/ Idea Tinkering Activities etc. shall be encouraged to be performed by students beyond the above stipulated hours

TH:1- IRON MAKING

L	T	P		
3	0	0		Course Code: MTPC202
Total Contact Hours				Theory Assessment
Theory		: 45Hrs	Total Marks: 100	End Term Exam 70
				Progressive Assessment 30
Pre Requisite		: Nil		
Credit		3		Category of Course: PC

RATIONALE:

Ironmaking course is to provide a comprehensive understanding of the processes involved in converting iron ore into a form suitable for steelmaking, covering raw materials, blast furnace operation, and emerging technologies, crucial for the steel industry and related fields

Course Outcomes (CO)

1. Knowledge of Raw materials and their property requirement for iron making.
2. Identify the required parameters required for blast furnace and auxiliary equipment's and measures to be taken for starting and troubleshooting of Blast furnace process.
3. Knowledge of physico-chemical phenomena taking place in blast furnace. Able to perform simple mass balance problems.
4. Identify the importance of modern techniques to improve quantity, quality of hot metal and minimization of waste.
5. Knowledge of alternative processes to be followed suitable to the local conditions in view of energy, environmental and efficiency considerations.

UNIT-I	(10 Hours) Introduction • Different routes for iron making • Raw Materials and their functions • Deposits of iron ores flux and coal in India with particular reference to Odisha Quality requirements of raw materials • Different types of iron ores • Composition and characteristics of raw materials • Evaluation of iron ores • Metallurgical coal, Difference between coal and coke • Required properties of coke for making iron • Flux and its types, Evaluation of Flux (available base & basicity) • Burden Preparation: Quality of burden (physical & chemical properties) • Agglomeration and its type (Preparation, Function and Quality requirement of Sinter, Comparison between Sintering and Pelletising) • Blast Furnace Fuel: Preparation, Function of coke and Quality requirement of coke • Auxiliary fuels • Factors affecting fuel consumption in blast furnace • Burden calculation for B/F operation (Material Balance & Heat Balance)	10
UNIT-II	(15 Hours)	15
	Blast furnace Operation • Blowing in, blowing out, Banking, Tapping, Fanning, Back draughting, Slag granulation & their utilization Blast furnace Accessories • Blast furnace refractories (Stack, Bosh and Hearth lining) • Blast furnace cooling arrangement (Stave, Hearth & bosh coolers) • Tap hole drilling and Mud gun machine • Cast house, Tuyeres assembly • Charging methods and process, Comparison between Double bell charging and bell less top charging • Gas cleaning plant • Blast furnace stoves Blast Furnace irregularities and Remedies • Hanging , Scaffolding, Channeling, Slip, Chilled hearth, Pillaring, Break out, Chocking of gas off take, Flooding and coke ejection through tap hole, Leaking tuyeres tap holes and coolers	

UNIT-III	(10 Hours) Chemistry of Blast Furnace operation • Blast furnace thermal, physical and chemical profile • Boudouard's equilibrium reaction • Direct & indirect reduction • Physical chemistry of blast furnace process: Reactions in stack, bosh, tuyere and hearth zone • Formation of primary slag, bosh slag, and hearth slag. Slag composition and its control, Metal-slag reactions, Control of hot metal composition. Modern Development of Blast furnace operation • Bell less charging, High top pressure operation, Humidification & oxygen enrichment of blast, External disiliconisation and desulphurization	10
UNIT-IV	(10 Hours) Alternative routes of iron making: • Overview of Sponge Iron Making Process • Conventional versus DRI Steel Making • Coal Based DRI process: SL/RN and Rotary hearth, Abnormalities in DRI • Gas based DRI Process: MIDREX and HYL • Smelting Reduction Process: COREX Production of Ferro-alloys • Different Ferro alloys and their use • Methods of producing Ferro alloys: carbothermic and aluminothermy reductions • Refining of Ferro alloys. • Production of individual Ferro alloys: Ferro manganese, Ferro chrome, charge chrome, ferrosilicon Fe-Ti, Fe-W, Fe-Mo and Fe-V	10

<u>Portion for Progressive Assessment:</u> Module:

-1 &2 Primary Textbooks

1. Iron & Steel Basforth Vol- I Chapman & Hall.

2. Iron making Tupkaray R.H. Khanna Publication

3. Iron & Steel Making A.K.Biswas SBA Publication

4. DRI Process and its relevance to India S. Dasgupta, T. K. Ray & B. Ray M.N. Dastur & companies Pvt Ltd.

5. Fundamentals of Sponge Iron making C.Mohapatra & D. Patnaik JJTP BBSR.

6. Sponge iron Production Direct Reduction of Iron

oxide, Amit Chatterjee, PHI

Reference Books

1. Blast Furnace Iron Making A.K.Biswas SBA Publisher.

2. DRI Process in Rotary kiln Alis Chalmers USA

3. Production of ferro alloys A. Riss, Y. Khodorrosky ForeignLanguage Publishing House

4. Alternate methods of iron making Surya Kumar Dutta & R.Saha S.Chand New Delhi,

5. An Introduction to physical chemistry of iron & steel making Ward-Hodder Stoughton in education

6. Introduction to Physical Chemistry of Iron and Steel Making, R.G Ward, Hodder &

Stoughton Educational; New edition

TH:2- PHYSICAL METALLURGY

L	T	P	Total Marks: 100	Course Code: MTPC204	
3	0	0			
Total Contact Hours				Theory Assessment	
Theory	: 45Hrs			End Term Exam	70
				Progressive Assessment	30
Pre Requisite	: Nil				
Credit	3			Category of Course: PC	

RATIONALE:

The rationale for a course in Physical Metallurgy is to provide a foundational understanding of how the structure, composition, and processing of metals and alloys influence their properties, enabling the design and optimization of materials for various applications

Course Outcomes:

By completing this course the student will have:

1. The fundamental principles of physical metallurgy, including crystal structures and imperfections.
2. Interpret phase diagrams and phase transformations, particularly the Iron-Carbon phase diagram.
3. The ability to identify the concepts of alloy design, phase diagrams and apply them to materials systems
4. The knowledge of physical metallurgical aspects of important engineering alloys

Detailed Contents:

UNIT-I	Basic Concepts of Physical Metallurgy (10 hours) Introduction to Metallurgy • Classification of materials: Metals, alloys, ceramics, polymers, composites • Structure of metals: Atomic bonding, metallic bonding • Imperfections in Solids: Point defects: Vacancies, interstitials, substitutional defects, Line defects: Edge and screw dislocations, Surface defects: Grain boundaries, twin boundaries and volume defects	10
UNIT-II	Solid Solutions & Solidification of pure metals & alloys: (15 hours) Solid Solutions: Solid solutions (substitutional, interstitial), Hume-Rothery rules, intermediate phases, Solidification of pure metals & alloys : Alloys and solid solution, solidification and crystallization, role of free energy thermodynamic potential in conversion of liquid to solid, super cooling, under cooling, degree of super cooling, mechanism of solidification/ crystallization, nucleation, critical size nucleus, spontaneous nucleation, relation between nucleation and grain growth, shape of crystals and solidification of ingot.	15
UNIT-III	Phase Diagrams & Phase Transformations: (10 hours) Phase Rule: Definitions of phase, component, degree of freedom, the phase rule and its applications. Unary Phase Diagrams: Pressure-temperature diagrams for pure substances. Binary Phase Diagrams: Interpretation of binary phase diagrams (eutectic, peritectic, eutectoid, peritectoid), lever rule, equilibrium and non-equilibrium cooling. Iron carbon diagram	10
UNIT-IV	Alloys and Their Properties (10 hours) Ferrous Alloys: • Plain Carbon Steels: Classification based on carbon content, their properties and applications. • Alloy Steels: Effects of alloying elements (Ni, Cr, Mo, V, W, Mn, Si) on properties, classification of alloy steels, applications, stainless and special steels • Cast Irons: Types of cast irons (grey, white, ductile, malleable), their microstructure, properties, and applications. Non-Ferrous Alloys: • Aluminum Alloys: Common aluminum alloys, their properties, and applications.	10

	• Copper Alloys: Brass, bronze, cupronickel, their properties, and applications. • Other Non-Ferrous Alloys: Brief overview of titanium alloys, nickel alloys, etc. Superalloys, shape memory alloys – classification, properties and applications	

Suggested books:

1. Physical Metallurgy: Principles and Practice, V. Raghavan, PHI Learning, Delhi, 2008.
2. Physical Metallurgy Principles, R. Abbaschian, R. E. Reed-Hill, Cengage Learning, 2009
3. "Materials Science and Engineering: An Introduction" – *William D. Callister, Jr.* (*Wiley*)
4. "Engineering Physical Metallurgy" – *Y. Lakhtin* (*Mir Publishers*)

Suggested reference books

1. Physical Metallurgy Vols. I, II, III, R.W. Cahn and P. Haasen, North Holland, 1996.
2. Light Metals, I.J. Polmear, Elsevier, 2005
3. "Phase Transformations in Metals and Alloys" – *David A. Porter & Kenneth E. Easterling* (*CRC Press*)
4. "Fundamentals of Physical Metallurgy" – *John D. Verhoeven* (*Wiley*)
5. "Physical Metallurgy" - Vijendra Singh (Standard Publishers Distributors.)

TH:3- INDUSTRIAL METALLURGY

L	T	P		
3	0	0		Course Code: MTPC206
Total Contact Hours			Total Marks: 100	Theory Assessment
Theory : 45Hrs				End Term Exam 70
				Progressive Assessment 30
Pre Requisite : Nil				
Credit 3				Category of Course: PC

RATIONALE:

Industrial Metallurgy is to equip students with the knowledge and skills to understand and apply the principles of materials science and engineering, particularly focusing on metals, alloys, and their industrial applications, ultimately contributing to the development of sustainable and efficient materials for various industries.

Course Outcomes:

After completing this course, the student should be able to:

1. Knowledge of Different Metal Joining Processes

To develop a comprehensive understanding of various metal joining processes, including welding, brazing, soldering.

2. Metallurgical Changes During Joining

To analyze the effects of joining processes on the mechanical properties of the materials being joined, including the heat-affected zone (HAZ), susceptibility to defects.

3. Understanding the Fundamentals of Powder Metallurgy

To gain a comprehensive understanding of the basic principles of powder metallurgy, including powder production, compaction.

4. Understanding Corrosion Fundamentals, Corrosion Prevention and Control

To gain a comprehensive understanding of the fundamental concepts of corrosion, including its causes, types, and electrochemical principles & to understand the various methods of corrosion prevention.

DETAILED CONTENTS:

UNIT-I	Welding Processes (20 Hours) Gas Welding: types of flames, equipment, steps, advantages, disadvantages and application of gas welding) , Arc Welding :various arc welding process such as -Gas Metal Arc Welding (GMAW) ,Gas Tungsten Arc Welding (GTAW) ,Shielded Metal Arc Welding (SMAW), Submerged Arc Welding (SAW) , Thermit Welding : principle, procedure, advantages and disadvantages of Thermit welding, Friction Stir Welding , Ultrasonic Welding, Additive Manufacturing with Metal Joining, Advanced Robotics and Automation in Metal Joining, Heat Affected Zone (HAZ) and its Effects, Weld Defects: Types of defects: Porosity, cracking, incomplete fusion, undercut	20
UNIT-II	Joining of Dissimilar Metals & Metallurgical Aspects of Metal Joining (5 Hours) Brazing and Soldering : Brazing- principle and various brazing methods of common ferrous and nonferrous metals.	5

	Soldering and various types of solders, basic steps of soldering of common metals	
UNIT-III	Powder Metallurgy (10 hours) Introduction to powder metallurgy, advantages, disadvantages and applications of Powder Metallurgy, primary and secondary characteristics of powders , different methods of powder production, different die-compaction techniques , continuous compaction	10
UNIT-IV	Corrosion (10 Hours) Introduction to corrosion, electrochemical corrosion and chemical corrosion, corrosion rate, Faraday's law of electrolysis and its deviation, EMF series & Galvanic Series, types of corrosion (Atmospheric Corrosion, , Galvanic corrosion, Intergranular corrosion, Stress corrosion cracking, corrosion fatigue) , Corrosion Prevention Methods: cathodic Protection, Anodic protection, Coatings & Inhibitors	10

<u>Portion for Progressive Assessment:</u> Module:-1 &2

Primary Textbooks

1. " Welding Technology"- O. P. Khanna – Dhanpat
2. " Introduction to Powder Metallurgy " – A.K.Sinha - L Hanpat Rai Publication
3. "Corrosion Engineering" -M.G. Fontana and Green -Mc Graw Hill
4. "Introduction to electrometallurgy and corrosion" -Saran & Narayan- Standard

Reference Books

1. "Welding: Principles and Applications" – Larry Jeffus - Delmar Cengage Learning
2. "The Welding Handbook" – American Welding Society (AWS) - American Welding Society
3. "Corrosion Engineering" – M. S. Revie - McGraw-Hill Education
4. "Introduction to Corrosion Science" – R. W. Revie – Springer
5. "Fundamentals of Corrosion: Mechanisms, Causes, and Preventive Methods" M. D. D. J. I. H. Jones- Elsevier

TH:4(A)- MATERIAL CHARACTERIZATION

L	T	P	Total Marks: 100	Course Code: MTPE202
3	0	0		
Total Contact Hours				Theory Assessment
Theory : 45Hrs				End Term Exam 70
				Progressive Assessment 30
Pre Requisite : Nil				
Credit 3				Category of Course: PE

RATIONALE:

The rationale for a course on Material Characterization is to equip students with the knowledge and skills to analyze and understand the properties of materials at various scales, enabling them to make informed decisions in material selection, design, and problem-solving.

Course Outcomes:

After completing this course, the student will be able to:

1. Determine crystal structures of materials
2. Analyse microstructure of materials at different length scales
3. Analyse defects and fracture surfaces of the tested materials
4. Indicate instrumentation associated with and operating principles of various techniques

Detailed Contents

UNIT-I	Module 1: Introduction to Material Characterization (5 Hours) Fundamentals of Material Characterization: Importance of material characterization in metallurgy, Classification of characterization techniques: Structural, chemical, mechanical, and thermal analysis, Selection criteria for characterization methods Specimen Preparation Techniques: Cutting, grinding, polishing, and etching, Sample preparation for different characterization methods (metals, ceramics, polymers)	5

UNIT-II	Module 2: Microstructural Characterization Techniques (15 Hours) Optical Microscopy (OM): Principles of optical microscopy, Bright-field and dark-field imaging, Grain size analysis using ASTM standards Scanning Electron Microscopy (SEM) & Energy Dispersive Spectroscopy (EDS): Working principle and components of SEM, Image contrast mechanisms and resolution, EDS for elemental composition analysis Transmission Electron Microscopy (TEM): Principles and applications of TEM, Diffraction contrast and phase identification Atomic Force Microscopy (AFM): Principles of AFM, different modes of operation (contact, tapping, non-contact). Surface topography, roughness measurement.	15
UNIT-III	Module 3: X-ray and Spectroscopic Characterization (15 Hours) X-ray Diffraction (XRD): Bragg's law and diffraction principles, Phase identification and crystallite size determination, Applications in metallurgy and materials science Spectroscopy Techniques: UV-Visible Spectroscopy: Absorption and bandgap analysis, Infrared (IR) Spectroscopy: Functional group identification, Raman Spectroscopy: Vibrational analysis of materials	15
UNIT-IV	Module 4: Thermal & Mechanical Characterization Techniques (10 Hours) Thermal Analysis Methods: Differential Scanning Calorimetry (DSC): Phase transformation studies, Thermogravimetric Analysis (TGA): Thermal stability and decomposition analysis, Dilatometry: Thermal expansion studies	10

Mechanical Characterization Techniques

- Hardness testing (Knoop)
- Nanoindentation for hardness measurement

Textbooks:

1. "Materials Characterization: Introduction to Microscopic and Spectroscopic Methods" – *Yang Leng* (*Wiley*)
2. "Material Characterization Techniques" – *S. Zhang & L. Li* (*CRC Press*)
3. "Characterization of Materials" – *E. N. Kaufmann* (*Wiley*)
4. "Scanning Electron Microscopy and X-ray Microanalysis" – *Joseph Goldstein et al.* (*Springer*)
5. "X-ray Diffraction: A Practical Approach" – *C. Suryanarayana & M. Grant Norton* (*Springer*)

Reference Books:

6. "Materials Characterization Techniques" – *Sam Zhang & Ashok Kumar* (*CRC Press*)

7. "Thermal Analysis of Materials" – *Robert Speyer* (*Marcel Dekker*)

8. "Elements of X-ray Diffraction" – B.D. Cullity (Pearson)

9. "Introduction to Scanning Tunneling Microscopy" – C. Julian Chen (Oxford University Press)

10. "Transmission Electron Microscopy: A Textbook for Materials Science" – David B. Williams & C. Barry Carter (Springer)

TH:4(B)- FUNCTIONAL MATERIAL

L	T	P	Total Marks: 100	Course Code: MTPE202 (B)
3	0	0		
Total Contact Hours				Theory Assessment
Theory : 45Hrs				End Term Exam 70
				Progressive Assessment 30
Pre-Requisite : Nil				
Credit 3				Category of Course: PE

RATIONALE:

Functional materials exhibit specific physical or chemical properties that make them suitable for advanced technological applications such as electronics, sensors, actuators, energy devices, and smart systems. Unlike structural materials, they are designed for their response to external stimuli (light, heat, stress, magnetic or electric fields). This subject introduces diploma students to the types, properties, applications, and fabrication methods of functional materials, preparing them for modern materials industries, electronics manufacturing, and energy sectors.

Course Outcomes:
After completing this course, students will be able to:

1. **Understand** the classification and characteristics of functional materials.
2. **Explain** the role of semiconductors, dielectrics, magnetic and optical materials.
3. **Identify** applications of smart materials and nanomaterials in real-world technologies.
4. **Relate** material structure to performance in various functional applications.

UNIT-I	Introduction to Functional Materials (10 periods) • Difference between structural and functional materials • Classification: Electronic, magnetic, optical, energy, and smart materials • Structure-property relationship • Processing and fabrication overview • Role of functional materials in emerging technologies	10

UNIT-II	• **Electronic and Magnetic Materials (12 periods)** • Conductors, semiconductors, and insulators • Intrinsic and extrinsic semiconductors • p-n junction and basic applications (diodes, solar cells, sensors) • Magnetic materials: soft and hard magnets • Ferrites and magnetic storage applications	12
UNIT-III	Optical, Dielectric, and Piezoelectric Materials (12 periods) • Optical materials: photoconductors, photoresistors, LEDs, lasers • Dielectrics: Permittivity, polarization, ferroelectricity • Piezoelectric materials and applications in sensors/actuators • Electro-optic and magneto-optic materials • Thermochromic and electrochromic materials	12
UNIT-IV	Smart and Energy Functional Materials (11 periods) • Shape memory alloys (SMA): NiTi and applications • Thermoelectric materials: Seebeck effect and devices • Superconducting materials: Properties and applications • Introduction to nanomaterials as functional materials • Applications in aerospace, biomedical, renewable energy, and electronics	11

Text Books

1. **“Functional Materials: Electrical, Dielectric, Electromagnetic, Optical and Magnetic Applications”** by Deborah D.L. Chung – Wiley
2. **“Materials Science and Engineering”** by V. Raghavan – PHI Learning Pvt. Ltd.

Reference Books

1. **“Materials Science”** by R.S. Khurmi & R.S. Sedha – S. Chand & Company Ltd.
2. **“Smart Materials and Structures”** by M.V. Gandhi & B.S. Thompson – CRC Press
3. **“Introduction to Materials Science for Engineers”** by James F. Shackelford – Pearson
4. **“Nanostructured Materials and Nanotechnology”** by Hari Singh Nalwa – Academic Press

TH:4(C)- PHASE TRANSFORMATIONS

L	T	P	Total Marks: 100	Course Code: MTPE202 (C)
3	0	0		
Total Contact Hours				Theory Assessment
Theory : 45Hrs				End Term Exam 70
				Progressive Assessment 30
Pre-Requisite : Nil				
Credit 3				Category of Course: PE

RATIONALE:

Phase transformations are fundamental to controlling the structure and properties of metals and alloys. From casting to welding and heat treatment, the engineering performance of materials is rooted in the microstructural changes that occur during phase changes. With increasing demand for high-performance materials in aerospace, automotive, and energy sectors, understanding traditional and emerging phase transformation mechanisms is essential for diploma students entering the metallurgical and materials industry.

Course Outcomes:

After completing this course, students will be able to:

1. **Understand** the thermodynamic and kinetic principles governing phase transformations.
2. **Interpret** phase diagrams and TTT/CCT curves for predicting microstructures.
3. **Explain** the mechanisms of diffusional and diffusionless transformations in alloys.
4. **Apply** knowledge of phase transformations to modern processes like additive manufacturing, advanced heat treatments, and high-performance alloy development.

UNIT-I	**Fundamentals of Phase Transformations (12 periods)** • Definition and classification: Diffusional (e.g., solidification, precipitation) vs. diffusionless (e.g., martensitic) transformations • Driving force for phase transformations – free energy changes and critical radius for nucleation • Homogeneous and heterogeneous nucleation – role of surfaces, interfaces, and inoculants • Growth mechanisms: planar and dendritic growth • Application overview: Grain refinement in casting, inoculants in aluminum and magnesium alloys	12

UNIT-II	Solidification and Cast Structures (12 periods) • Fundamentals of solidification: nucleation and growth under equilibrium and non-equilibrium conditions • Dendritic solidification: columnar vs. equiaxed grains, morphology control • Segregation: microsegregation (coring), macrosegregation, and banding • Eutectic and peritectic solidification reactions; undercooling and constitutional supercooling • Recent development: *Rapid solidification and undercooling techniques in additive manufacturing (AM)* • Practical insight: Design of casting alloys for defect reduction and structure control	12
UNIT-III	Solid-State Phase Transformations (13 periods) • Precipitation: nucleation, growth, over-aging, and coarsening • Eutectoid transformations (e.g., austenite to pearlite): lamellar growth, interlamellar spacing • Martensitic transformation: mechanism, habit plane, crystallography, shape memory effects • Recrystallization: driving force, critical temperature, texture evolution • Recovery and grain growth – normal and abnormal growth • *Thermo-mechanical processing, Q&P (quenching and partitioning) steels, TRIP/TWIP steels* • Case studies: Phase transformation paths in stainless steel, aluminum alloys, and titanium alloys	13

UNIT-IV	Time-Temperature Concepts and Emerging Applications (8 periods) • Isothermal transformation diagrams (TTT): features, construction, interpretation • Continuous Cooling Transformation (CCT) diagrams: importance in welding and manufacturing • Bainite transformation: upper and lower bainite, morphology, mechanical properties • Microstructure-property correlation through TTT/CCT – hardness, toughness, ductility • Applications: *Phase transformations in laser sintering, powder metallurgy, additive manufacturing*	8

Text Books

1. **"Phase Transformations in Metals and Alloys"** by D.A. Porter & K.E. Easterling – CRC Press
2. **"Physical Metallurgy Principles"** by Reza Abbaschian, Lara Abbaschian, and Robert E. Reed-Hill – Cengage Learning

Reference Books

1. **"Transformations in Metals"** by Paul G. Shewmon – McGraw Hill
2. **"Introduction to Physical Metallurgy"** by Sidney H. Avner – Tata McGraw Hill
3. **"Steels: Microstructure and Properties"** by Harry Bhadeshia & Robert Honeycombe – Butterworth-Heinemann
4. **"Computational Materials Engineering"** by David Raabe – Wiley

TH:5(A)- NON-FERROUS EXTRACTIVE METALLURGY

L	T	P	Total Marks: 100	Course Code: MTPE204	
3	0	0			
Total Contact Hours				Theory Assessment	
Theory	: 45Hrs			End Term Exam	70
				Progressive Assessment	30
Pre-Requisite	: Nil				
Credit	3			Category of Course: PE	

RATIONALE:

Non-Ferrous Extractive Metallurgy is to provide students with the knowledge and skills needed to understand and apply the principles of extracting and processing non-ferrous metals, which are crucial for various industrial applications and technological advancements.

Course Outcomes:

1. Understanding the fundamentals of non-ferrous ores:

Knowledge of different types of non-ferrous ores, their chemical compositions, and the challenges associated with their extraction.

2. Ore extraction techniques:

Knowledge of necessary processes for the extraction of ore, such as pyrometallurgy, hydrometallurgy and electrometallurgy.

3. Specific metal extraction processes:

In-depth study of the specific processes used to extract individual non-ferrous metals like aluminum (Bayer process, Hall-Heroult process), copper (froth flotation, smelting, electrorefining), zinc (electrolytic zinc process), and precious metals (cyanidation, refining).

Contents:

<table>
<tr><td>UNIT-I</td><td>(15 Hours)
Introduction
Ores and minerals, gangue, flux and slag
matte and speiss
Non-ferrous ore reserves in India & non ferrous industries in India.
Methods of Extraction
Pyrometallurgical processes: roasting and different roasting methods, smelting and different smelting practices Flash smelting, hearth smelting, matte smelting 3.5 Explain the method of distillation and sublimation 3.6 Explain the process of converting of matte and pig iron
Hydrometallurgical process: stages of hydrometallurgical process, flow diagram for hydrometallurgical extraction, leaching and different leaching methods (bacterial leaching and pressure leaching)</td><td>15</td></tr>
<tr><td></td><td>Electrometallurgical process: electrolysis, electro wining, electro refining</td><td></td></tr>
<tr><td>UNIT-II</td><td>(10 Hours)

Extraction of Metals from Sulphide Ores
Pyrometallurgical Extraction of Copper: roasting of copper ore, matte smelting of copper ore. conversion of copper matte, refining of copper, uses of copper.
Pyrometallurgical and Hydrometallurgical Method of Extraction of Zinc: roasting of zinc ore concentrates, extraction by vertical retort process, refining of zinc. Leaching and preparation zinc base solution, electrolysis of zinc solution, uses of zinc
Pyrometallurgical Method of Nickel Extraction: roasting of nickel ore, smelting of nickel concentrate, refining of nickel, uses of nickel.</td><td>10</td></tr>
<tr><td>UNIT-III</td><td>(10 Hours)
Extraction of Metals from Oxide ores
Extraction of aluminum: Bayer’s process of alumina production, fused salt electrolysis of alumina by Hall Heroult process, refining of aluminum, anode effect, uses of aluminum.
Extraction of Metals from Halides.
Extraction of Titanium: extraction of titanium, treatments given to titanium ore, chlorination and mag, reduction for titanium extraction, refining of titanium (distillation, uses of titanium.</td><td>10</td></tr>
</table>

UNIT-IV	(10 Hours) Extraction of Precious Metals • Extraction of gold: cyanidation for gold extraction, uses of gold. • Extraction of Lithium: electrolysis for Li extraction, properties of Li and uses of Li. • Production of Secondary Metals. Process for production of copper, lead, zinc &. aluminum metals from scraps.	10

Text books

1. Non Ferrous Production Metallurgy Bray J.L J.Wiley

2. Non-Ferrous Metallurgy of Metal Dannis W.H. Isaac Pitman & Sons

3. Extraction or Non- Ferrous Metal Roy, Sridhar & Abraham EWP

4. Rare Metal Extraction W. D. Jamrack Pergamon Press Reference Books

Reference books

1. Extraction of Nuclear and Non-ferrous Metals (Topics in Mining, Metallurgy and Materials Engineering) Hardcover by Sujay Kumar Dutta , D. R. Lodhari; Pub. Springer

2. Modern Technology of Non-ferrous Metals and Metal Extraction by Engineers India research Board

TH:5(B)- NON-METALLIC MATERIAL

<table>
<tr><td>L</td><td>T</td><td>P</td><td rowspan="2">Total Marks: 100</td><td rowspan="2">Course Code: MTPE204 (B)</td></tr>
<tr><td>3</td><td>0</td><td>0</td></tr>
<tr><td colspan="3">Total Contact Hours</td><td rowspan="6"></td><td>Theory Assessment</td></tr>
<tr><td colspan="3">Theory : 45Hrs</td><td>End Term Exam 70</td></tr>
<tr><td colspan="3"></td><td>Progressive Assessment 30</td></tr>
<tr><td colspan="3" rowspan="2">Pre-Requisite : Nil</td><td></td></tr>
<tr><td></td></tr>
<tr><td colspan="3">Credit 3</td><td>Category of Course: PE</td></tr>
</table>

RATIONALE:

Non-metallic materials such as polymers, ceramics, glasses, composites, and adhesives have emerged as key materials in modern engineering applications due to their unique properties like light weight, corrosion resistance, and high thermal/electrical insulation. Understanding the characteristics, processing methods, and applications of these materials is essential for diploma engineers to make informed choices in materials selection and contribute effectively in manufacturing, quality control, and research domains.

Course Outcomes:

After completing this course, students will be able to:

1. **Identify** various classes of non-metallic materials used in engineering applications.
2. **Explain** the basic structure, properties, and processing techniques of polymers, ceramics, and composites.
3. **Compare** the properties of non-metallic materials with metals and recognize their advantages and limitations.
4. **Select** appropriate non-metallic materials for specific applications based on functional requirements.

<table>
<tr><td>UNIT-I</td><td>Polymers (12 periods)
Introduction to polymers: Classification (thermoplastics, thermosets, elastomers)
Polymerization techniques: Addition and condensation
Structure-property relationship
Mechanical, thermal, and chemical properties
Applications in engineering (pipes, gears, coatings, etc</td><td>12</td></tr>
</table>

UNIT-II	**Ceramics and Glasses (10 periods)** • Classification of ceramics: Traditional and advanced • Properties of ceramics (brittleness, hardness, corrosion resistance) • Glass structure and common types • Fabrication and processing techniques (sintering, vitrification) • Uses in thermal barriers, electronics, refractories	10
UNIT-III	**Composites and Textiles (13 periods)** • Definition and classification of composites • Matrix and reinforcement materials • Types: Particle reinforced, fiber reinforced, structural composites • Processing: Hand lay-up, pultrusion, resin transfer molding • Basic introduction to engineering textiles and their applications	13
UNIT-IV	**Adhesives and Foams (10 periods)** • Classification and types of adhesives (epoxy, acrylic, etc.) • Bonding mechanisms and surface preparation • Properties and applications of structural adhesives • Introduction to polymer foams: Open/closed cell, insulation, cushioning	10

Text Books

1. **"Polymer Science"** by V.R. Gowariker – New Age International Publishers.
2. **"Introduction to Ceramics"** by Kingery, Bowen, and Uhlmann – Wiley India Pvt Ltd.
3. **"Composite Materials: Science and Engineering"** by Krishan K. Chawla – Springer.
4. **"Materials Science"** by R.S. Khurmi and R.S. Sedha – S. Chand & Company Ltd.

Reference Books

1. **"Materials Science and Engineering: An Introduction"** by William D. Callister – Wiley.
2. **"Engineering Materials: Properties and Selection"** by Kenneth G. Budinski – Pearson.
3. **"Textbook of Polymer Science"** by Fred W. Billmeyer – Wiley India Pvt Ltd.

TH:5(C)- ENERGY MATERIAL

<table>
<tr><td>L</td><td>T</td><td>P</td><td rowspan="2">Total Marks: 100</td><td rowspan="2">Course Code: MTPE204 (C)</td></tr>
<tr><td>3</td><td>0</td><td>0</td></tr>
<tr><td colspan="3">Total Contact Hours</td><td rowspan="6"></td><td>Theory Assessment</td></tr>
<tr><td colspan="3">Theory : 45Hrs</td><td>End Term Exam 70</td></tr>
<tr><td colspan="3"></td><td>Progressive Assessment 30</td></tr>
<tr><td colspan="3" rowspan="2">Pre-Requisite : Nil</td><td></td></tr>
<tr><td></td></tr>
<tr><td colspan="3">Credit 3</td><td>Category of Course: PE</td></tr>
</table>

RATIONALE:

The global push toward sustainable and renewable energy technologies has made understanding energy materials essential for modern engineers. Materials play a key role in batteries, fuel cells, solar cells, supercapacitors, and other energy conversion/storage devices. This course provides fundamental knowledge on the materials science of energy devices, their properties, fabrication, performance, and challenges, preparing diploma engineers for industries in clean and renewable energy.

Course Outcomes:

After completing this course, students will be able to:

1. **Explain** the principles of major energy storage and conversion devices.
2. **Identify** suitable materials for different energy applications and describe their properties.
3. **Understand** the synthesis, processing, characterization, and performance aspects of energy materials.
4. **Evaluate** energy technologies for environmental friendliness and analyze failure mechanisms of energy materials.

<table>
<tr><td>UNIT-I</td><td>Global Energy Scenario & Basics of Energy Materials (10 periods)
Overview of global and Indian energy demands and challenges.
Evaluation of energy sources from a clean energy perspective; carbon footprint.
Introduction to materials for energy conversion and storage.
Desired properties of energy materials (ionic/electronic conductivity, stability, etc.).
Overview of synthesis and characterization techniques.</td><td>10</td></tr>
</table>

UNIT-II	**Materials for Batteries & Supercapacitors (13 periods)** • Working principles of primary and secondary batteries. • Materials for electrodes and electrolytes in Li-ion, lead-acid, and emerging batteries. • Solid-state electrolytes. • Supercapacitors: Principles, carbon-based materials, metal oxides, conducting polymers. • Characterization and performance evaluation of battery and supercapacitor materials.	13
UNIT-III	Materials for Fuel Cells & Solar Cells (13 periods) • Fuel cells: Types (PEMFC, SOFC, MCFC), electrode/catalyst materials. • Membranes and bipolar plates. • Working principles and materials for solar cells (silicon-based, thin-film, perovskite). • Efficiency-limiting factors, stability, and degradation. • Environmental impacts of fuel cell and photovoltaic technologies.	13
UNIT-IV	Other Energy Devices & Future Trends (9 periods) • Wind energy and mechanical energy storage materials. • Hydrogen production, storage materials (metal hydrides, porous materials). • Thermoelectric materials: Principles, materials selection. • Emerging trends: Solid-state batteries, flexible energy devices. • Failure analysis and safety considerations in energy materials.	9

Text Books

1. **"Renewable Energy: Power for a Sustainable Future"** – Godfrey Boyle, Oxford University Press, 2004.
2. **"Electrochemical Power Sources: Batteries, Fuel Cells, and Supercapacitors"** – Vladimir S. Bagotsky, Wiley, 2009.

Reference Books

1. **"Materials for Sustainable Energy:** A Collection of Peer-Reviewed Research and Review Articles" – Co-published by Nature Publishing and World Scientific, 2011.
2. **"Handbook of Battery Materials"** – Claus Daniel & Jürgen O. Besenhard, Wiley-VCH, 2012.
3. **"Principles and Applications of Electrochemistry"** – D.R. Crow, Springer, 1994.

PR:1- INDUSTRIAL METALLURGY LAB

<table>
<tr><td>L</td><td>T</td><td>P</td><td rowspan="7">Total Marks: 50</td><td rowspan="2">Course Code: MTPC208</td></tr>
<tr><td>0</td><td>0</td><td>4</td></tr>
<tr><td colspan="3">Total Contact Hours</td><td>Practical Assessment</td></tr>
<tr><td colspan="3">Theory : 60Hrs</td><td>End Exam 15</td></tr>
<tr><td colspan="3"></td><td>Progressive Assessment 35</td></tr>
<tr><td colspan="3" rowspan="2">Pre Requisite : Nil</td><td></td></tr>
<tr><td></td></tr>
<tr><td colspan="3">Credit 2</td><td></td><td>Category of Course: PC</td></tr>
</table>

RATIONALE:

Industrial Metallurgy Lab course is to provide practical, hands-on experience in understanding and applying metallurgical principles, crucial for engineers and scientists working with metals and alloys in various industries, from manufacturing to quality control. Course Outcomes

Course outcomes:

After completing this course, the student will be able to:

1) Perform laboratory experiments related to different processes, along with associated data analysis and interpretation of results
2) Identify the tools and machinery involved in the various experiments related to Industrial Metallurgy.

List of Experiments:

UNIT-I	Temperature measurement using Thermocouple and pyrometer, Calibration Principles and Standards, Hands-on Calibration Experiment of Calibrating a Thermocouple (15 Hours)	15
UNIT-II	Friction Stir Welding, Microstructure analysis of welded joints, Brazing and Soldering:	15

	Demonstration of brazing and soldering techniques. (15 Hours)	
UNIT-III	Introduction to Corrosion and Testing, Weight Loss Method, Electrochemical Techniques, Salt Spray Testing, Humidity Chamber Testing, Galvanic Corrosion Testing (15 Hours)	15
UNIT-IV	Mixing Metallic Powder, Ceramic powders, Compaction, Making Pellets, Sintering. (15 Hours)	15

Suggested books:

1. "Temperature Measurement and Control" by J. F. W. Bell (CRC Press)

2. "Corrosion Testing Made Easy: The Basics" by Harry E. Chandler (NACE International)

3. "ASM Handbook, Volume 13A: Corrosion: Fundamentals, Testing, and Protection" (ASM International)

4. "Friction Stir Welding and Processing" by Rajiv S. Mishra and M. Wayne (ASM International)

5. "Powder Metallurgy Science, Technology and Applications" by P. C. Angelo and R. Subramanian (PHI Learning Pvt. Ltd.)

6. "An Introduction to Powder Metallurgy" by F. Thummler and R. Oberacker (Routledge)

PR:2- MODELLING AND SIMULATION LAB

L	T	P		Course Code: MTPC210	
0	0	4			
Total Contact Hours				Practical Assessment	
Theory	: 60Hrs		Total Marks: 50	End Exam	15
				Progressive Assessment	35
Pre Requisite	: Nil				
Credit	2			Category of Course: PC	

RATIONALE:

The lab aims to bridge the gap between theoretical knowledge and practical application by allowing students to build and test models, simulating real-world scenarios.

Course Outcomes:

After completing this course, the student will be able to:

1) To utilize computational tools to analyze and predict metallurgical processes and material properties.
2) Use computational modeling to identify optimal processing conditions for desired material properties, minimizing trial-and-error experimentation.
3) Apply numerical modeling techniques to simulate metallurgical processes like casting, and rolling for performance evaluation.
4) Analyze simulation results to predict material behavior under different manufacturing conditions and optimize process parameters.

List of Experiments:

1: Quantification of grain size from experimental microstructures using computational techniques.

2: Determination of phase fraction of a multiphase sample using computer software.

3: Demonstration of atomic structure and defects.

4: Demonstration of precipitate growth kinetics.

5: Demonstration of Nucleation and growth process during solidification.

6. Introduction to MATLAB/ANSYS/SolidWorks for Simulation

- Basics of numerical modelling and simulation software.

7. Casting Solidification Simulation

- Modelling the solidification process in metal casting.

8. Stress-Strain Analysis of a Metal Rod Under Tensile Load

- Applying tensile stress on a metallic specimen and analyzing deformation.

9 Rolling Process Simulation

- Simulating metal rolling process and observing deformation patterns.

10 Forging Simulation of a Billet

- Analyzing stress distribution during hot forging.

11. Microstructural Evolution During Heat Treatment

- Simulation of phase transformations in steel during quenching.

12. Computational Fluid Dynamics (CFD) in Metallurgy

a) Flow Simulation in a Continuous Casting Mold

- Simulating molten metal flow in a mold using CFD software.

b) Gas Flow Simulation in a Blast Furnace

- Studying the impact of air velocity and pressure on furnace performance

13. Analysis of various types of crystal defects using simulation.

Suggested books:

1) Understanding Molecular Simulation, Second Edition: From Algorithms to Applications (Computational Science): Daan Frenkel, Berend Smit for molecular dynamics
2) Electronic Structure: Basic Theory and Practical Methods (Vol 1): Richard M. Martin for density functional theory
3) Computational Physics: Jos Thijssen for computational physics
4) A Guide to Monte Carlo Simulations in Statistical Physics: David P. Landau, Kurt Binder for Monte Carlo techniques
5) S. S. Rao – "Engineering Optimization: Theory and Practice," Wiley.
6) M.K. Verma – *"Computational Methods in Engineering,"* PHI Learning.
7) K. Lalit & R. K. Gupta – *"Finite Element Analysis Using ANSYS 18.0,"* Wiley.
8) Shyam Bajpai – *"Practical Finite Element Analysis,"* Finite to Infinite.
9) Amos Gilat – *"MATLAB: An Introduction with Applications,"* Wiley.
10) S. V. Rao – *"Applied Numerical Methods for Engineers Using MATLAB & C,"* Pearson.
11) H. Versteeg & W. Malalasekera – *"An Introduction to Computational Fluid Dynamics: The Finite Volume Method,"* Pearson.
12) T. Wesseling – *"Principles of Computational Fluid Dynamics,"* Springer.

PR:3- MATERIAL CHARCTERIZATION LAB

L	T	P		
0	0	4	Total Marks: 50	Course Code: MTPC212
Total Contact Hours				Practical Assessment
Theory : 60Hrs				End Exam 15
				Progressive Assessment 35
Pre Requisite : Nil				
Credit 2				Category of Course: PC

RATIONALE:

The rationale for a Materials Characterization Lab course is to provide students with hands-on experience and a comprehensive understanding of the principles, techniques, and applications of various analytical methods used to characterize materials, enabling them to analyze and interpret experimental data for research and engineering applications.

Course Outcomes (COs):

Upon successful completion of the Material Characterization Laboratory course, students will be able to:

1. Ability to prepare sample for various materials characterization techniques.
2. Interpret the data generated, and select appropriate methods to analyze the structure.
3. Identify the key features of a material at the micro for research and development purposes.

List of Experiments:

(Student are required to perform at least six experiments)

Module 1: Metallographic study of cylindrical/cubical nonferrous alloy sample by grinding, polishing and etching.

Module 2: Metallographic study of thin sheet of ferrous sample by using mounting press.

Module 3: Preparation of sample for study in SEM using electro polishing technique.

Module 4: Determination of grain size by linear intercept method using photomicrography.

Module 5: Fractographic study of tensile tested sample.

Module 6: Determining the crystal structure and lattice parameters of a material using XRD.

Module 7: Studying phase transitions and heat capacity changes with temperature using DSC.

Module 8: Study of various SEM and TEM micrographs.

Suggested books:

1. "Materials Characterization: Introduction to Microscopic and Spectroscopic Methods" – *Yang Leng* (*Wiley*)
2. "Material Characterization Techniques" – *S. Zhang & L. Li* (*CRC Press*)
3. "Characterization of Materials" – *E. N. Kaufmann* (*Wiley*)
4. "Scanning Electron Microscopy and X-ray Microanalysis" – *Joseph Goldstein et al.* (*Springer*)
5. "X-ray Diffraction: A Practical Approach" – *C. Suryanarayana & M. Grant Norton* (*Springer*)

PR:4- MINOR PROJECT

L	T	P	Total Marks: 100	Course Code: PR202
0	0	4		
Total Contact Hours				Project Assessment
Practical : 60Hrs				End Exam 30
				Progressive Assessment 70
Pre Requisite : Nil				
Credit 2				Category of Course: PR

RATIONALE:

Mini-projects help students in different ways like the formation of groups, understanding group behavior, improving communication skills, learning in-depth with minimum time, interaction with the guide and outside agencies, thinking about final year projects, etc. it is observed that students are always excited to work on "something new topic in Engineering" because of their interest in learning in the implementation of knowledge in actual fields rather than classes. It will be appreciated if students involve some experimental works, case studies, site visits, and industrial projects, if possible.

The procedure of Evaluation: Normally, evaluation of mini-projects is done through presentations by a group of students in front of two or more faculty, and assessment of the individual student is done by faculty and the average of marks is worked out.

COURSE OUTCOMES:

After completion of the course, the students will be able to

- Integrate their knowledge and skills to develop prototype models in their field.
- Develop professional values and ethical standards.
- Handle real life challenges by making effective decisions to complete a project work.
- Show skills in developing real world applications

STUDENT’S ACTIVITY

Students will do their project work as per guidance from their guide (faculty member).

A suggestive criterion for assessing student performance by the external (preferably person from industry) and internal (teacher) examiner is given in table below:

Sl. No.	Performance Criteria
1.	Selection of project assignment
2.	Planning and execution of considerations
3.	Quality of performance
4.	Providing solution of the problems or production of final product
5.	Sense of responsibility
6.	Self-expression/ communication/ Presentation skills
7.	Interpersonal skills/human relations
8.	Report writing skills
9	Viva voce

The teachers are free to evolve other criteria of assessment, depending upon the type of project work.

It is proposed that the institute may organize an annual exhibition of the project work done by the students and invite leading Industrial organizations to such an exhibition.

ESSENCE OF INDIAN KNOWLEDGE AND TRADITION

L	T	P	Total Marks: NA	Course Code: AU202	
2	0	0			
Total Contact Hours				**Theory Assessment**	
Theory	**: 30Hrs**			**End Term Exam**	**: 0**
				Progressive Assessment*	**: 0**
Pre-Requisite	**: Nil**				
Credit	**: 0**			**Category of Course: Mandatory**	

***Mandatory Audit Courses will be assessed only for confirmation of student learning without reflecting in the total scores or Credit.**

RATIONALE: Considering the need of protecting Indian knowledge and tradition, the diploma level students of Automobile Engineering should be facilitated the concepts Indian traditional knowledge and to make Them understand the importance of roots of knowledge system and methods of application in today's life and how to protect traditional knowledge system. Interpretation of the concepts of Intellectual property to protect the traditional knowledge as well as importance of Traditional knowledge in Agriculture and Medicine must be known.

COURSE OUTCOME:

After completion of the course, students will be able to:

1. Discuss the concepts of traditional Indian knowledge and roots of knowledge system and indigenous knowledge system.
2. Explain the technique of protection of traditional Indian knowledge.
3. Discuss legal frameworks of traditional knowledge.
4. State intellectual property rights.
5. State traditional knowledge in Different Sectors.

DETAILED COURSE CONTENTS:

UNIT	TOPIC/SUB-TOPIC	ALLOTED HOURS
1	Introduction to traditional knowledge: Define traditional knowledge, nature and characteristics, scope and importance, kinds of traditional knowledge (Unani / Siddha/ Ayurveda), Indigenous Knowledge (IK), characteristics, traditional knowledge vis-a-vis indigenous knowledge, traditional knowledge of Odisha	07

2	Protection of traditional knowledge (TK): The need for protecting traditional knowledge, Significance of TK Protection, value of TK in global economy, Role of Government to harness TK.	07
3	Legal framework and TK: The Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006, Plant Varieties Protection and Farmer's Rights Act, 2001 (PPVFR Act); The Biological Diversity Act 2002 and Rules 2004, the protection of traditional knowledge bill, 2016.	06
4	Traditional knowledge and intellectual property: Systems of traditional knowledge protection, Legal concepts for the protection of traditional knowledge, Patents and traditional knowledge, Strategies to increase protection of traditional knowledge, Geographical Indications (GI).	04
5	Traditional Knowledge in Different Sectors: Traditional knowledge and engineering, Traditional medicine system, TK in agriculture, Traditional societies depend on it for their food and healthcare needs, Importance of conservation and sustainable development of environment, Management of biodiversity, Food security of the country and protection of TK	06

REFERENCES:

1. Traditional Knowledge System in India, by Amit Jha, 2009.
2. "Knowledge Traditions and Practices of India" Kapil Kapoor.
3. Madhya Himalayi Sanskriti mein Gyan, Vigyan evam Paravigyan by Prof PC Pandey.

SUGGESTED ONLINE LINK:

Web Links: 1.https://www.youtube.com/watch?v=LZP1StpYEPM
2.http://nptel.ac.in/courses/12110600/