GUJARAT TECHNOLOGICAL UNIVERSITY

Program Name: Diploma Engineering

Level: Diploma

Branch: Metallurgy Engineering

Subject Code : DI04021011

Subject Name: Physical Metallurgy - II

w. e. f. Academic Year:	2025-26
Semester:	4th
Category of the Course:	PCC

Prerequisite:	Students should have completed Physical Metallurgy I, covering crystallography, crystal structures (BCC, FCC, HCP), crystal defects, solidification, cooling curves, and basic phase diagrams. A sound understanding of engineering materials, their properties, material testing, basic chemistry, and engineering mathematics including percentage calculations and graphical interpretation is essential for grasping advanced ferrous and non-ferrous metallurgy in this course.
Rationale:	Physical Metallurgy II is a professional elective designed to equip diploma students with essential knowledge of ferrous and non-ferrous metallurgy for careers in metallurgical industries, quality control, research, and manufacturing. The course covers critical concepts such as the Fe–Fe_3C diagram, phase transformations, and microstructure–property relationships, enabling students to select materials, optimize heat treatments, troubleshoot defects, and ensure quality in industrial production. Practical laboratory work develops skills in metallographic preparation, microscopic examination, and phase diagram interpretation.

Course Outcome:

After Completion of the Course, Student will able to:

No	Course Outcomes	RBT Level
01	Explain the allotropy of iron and interpret the Fe–Fe_3C diagram with key reactions and phase transformations.	U
02	Classify steels and explain phase transformations, microstructures, and properties of plain carbon steels.	A
03	Classify different types of cast irons and relate their composition and microstructure to mechanical properties and practical engineering applications.	A
04	Describe the structure and applications of important non-ferrous alloys, including copper, aluminum, and nickel-based systems, as well as Babbitt alloys.	U

**Revised Bloom's Taxonomy (RBT)*

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Teaching and Examination Scheme:

Teaching Scheme (in Hours)			Total Credits L+T+ (PR/2)	Assessment Pattern and Marks				Total Marks
				Theory		Practical		
L	T	PR	C	ESE (E)	PA(M)	PA(I)	ESE (V)	
3	0	2	4	70	30	20	30	150

Course Content:

Unit No.	Content	No. of Hours	% of Weightage
1.	**Iron – Iron Carbide (Fe–Fe_3C) Equilibrium Diagram** 1.1 Allotropy of Iron 1.2 Fe - Fe_3C Equilibrium Diagram 1.3 Invariant Reactions and Critical Temperatures 1.4 Phases and Microconstituents in Fe–C Alloys 1.5 Application of Lever Rule in Fe–Fe_3C Diagram 1.6 Relationship Between Carbon Content, Microstructure, and Mechanical Properties	12	30
2.	**Steels: Classification, Phase Transformations, and Microstructures** 2.1 Definition and Classification of Steels 2.2 Phase Transformation and Microstructure of Plain Carbon Steels 2.3 Properties and Applications of Low Carbon Steels, Medium Carbon Steels and High Carbon Steels.	10	20
3.	**Cast Irons: Classification, Microstructure, Properties, and Applications** 3.1 Definition and Classification of Cast Irons 3.2 Phase Transformation and Microstructure of White Cast Iron 3.3 Composition, Microstructure, Properties, and Applications of Various Cast Irons like White Cast Iron, Grey Cast Iron, Malleable Cast Iron and Ductile Cast Iron.	11	25
4.	**Physical Metallurgy of Non-Ferrous Alloys (Cu, Al, and Other Systems)** 4.1 Introduction to Non-Ferrous Alloys 4.2 Copper and Its Alloys: Brasses and Bronzes 4.3 Aluminium and Its Alloys: Al-Cu, Al-Si and Al-Mg 4.4 Nickel and Its Alloys: Monel, Inconel and Nichrome	12	25

	4.5 Pb and Sn based Babbits Alloys		
	Total	**45**	**100**

Suggested Specification Table with Marks (Theory):

Distribution of Theory Marks(in %)					
R Level	**U Level**	**A Level**	**N Level**	**E Level**	**C Level**
25	40	35	0	0	0

Where R: Remember; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create (as per Revised Bloom's Taxonomy)

References/Suggested Learning Resources:

(a) Books:

Sr. No.	Title of Book	Author	Publication with place, yearand ISBN
1	Introduction to Physical Metallurgy	Sidney H. Avner	Tata McGraw-Hill Education Pvt. Ltd, New Delhi, 2012, ISBN: 0-07-002499-5, ISBN-13: 978-0-07-463006-8, ISBN-10: 0-07-463006-5
2	Physical Metallurgy for Engineers	Donald S. Clark, Wilbur R. Varney	CBS Publishers And Distributors Pvt Ltd, New Delhi, 2004, ISBN: 81-7671-035-0
3	Physical Metallurgy	Vijendra Singh	Standard Publishers Distributors, Delhi, 2013, ISBN-10: 8186308636, ISBN-13: 978-8186308639
4	Engineering Physical Metallurgy	Y. Lakhtin	Mir Publishers - Moscow & CBS, New Delhi, 2005, ISBN: 978-93-895-6570-6
5	Physical Metallurgy: Principles and Practice	V. Raghavan	PHI Learning Pvt. Ltd, New Delhi, 2015, ISBN: 8120330129, ISBN-10: 9788120351707, ISBN-13: 978-8120351707
6	Material Science and Metallurgy	Kodgire	Everest Publishing House, Pune, 2018, ISBN: 978-81-7446-916-5

(b) Open-source software and website:

1. NPTEL: Principles of Physical Metallurgy

An introductory course covering the fundamentals of physical metallurgy.
https://nptel.ac.in/courses/113105023

2. MIT Open Course Ware: 3.40J Physical Metallurgy (Fall 2009)
   Graduate-level course focusing on the relationship between the structure and properties of materials, emphasizing metals.
   https://ocw.mit.edu/courses/3-40j-physical-metallurgy-fall-2009/
3. ALISON – The Basic Science of Metallurgy
   Free online course covering fundamental concepts of metallurgy, including crystal structures, solidification, and heat treatment.
   Link: https://www.classcentral.com/tag/metallurgy
4. Class Central – Metallurgy Courses
   A curated list of over 20 free online metallurgy courses from various platforms, covering topics like physical metallurgy, materials science, and engineering.
   Link: https://www.classcentral.com/tag/metallurgy
5. DoITPoMS – Materials Science Teaching Resources
   Offers interactive teaching and learning packages focusing on various aspects of materials science, including phase diagrams and microstructure.
   Link: https://www.doitpoms.ac.uk/index.php
6. https://www.youtube.com/watch?time_continue=44&v=5cpdJ3IGGDc&feature=emb_title

Suggested Course Practical List:

No.	Practical Outcomes (PrOs)	Unit	Approx.

		No.	Hrs. required
1	Drawing and Labeling the Fe–Fe_3C Equilibrium Diagram.	I	04
2	Identifying Invariant Reactions and Critical Temperatures.	I	02
3	Application of the Lever Rule for Hypoeutectoid, Eutectoid, and Hypereutectoid Steels.	I	04
4	Preparation and Microscopic Observation of also properties and applications of the Low, Medium, and High Carbon Steels.	II	06
5	Microscopic Examination and Comparison of Microstructures of Various Cast Irons.	III	06
6	Drawing and Labeling Binary Phase Diagrams of Copper Alloys (Cu-Zn, Cu-Sn).	IV	04
7	Drawing and Labeling Binary Phase Diagram of Aluminium Alloy (Al-Si)	IV	04
Total		**30**	

List of Laboratory/Learning Resources Required:

Sr. No.	Equipment Name with Broad Specifications
1	Metallurgical Microscope (up to 1000X magnification)
2	Bench vise, Manual Hacksaw and HSS hacksaw blade
3	Cold mounting molds
4	Wheel Grinder and Belt Grinder
5	Emery Papers (120, 220, 320, 400, 600, 800, 1000, 1200, 1500, 2000, 3000 grit)
6	Double Disc Polishing Machine, Electrolytic polishing and etching machine
7	Chemicals – Epoxy resin, LR grade of Nitric acid, Ethanol, Picric acid, Iron(III) chloride, Hydrochloric acid, Hydrofluoric acid, Phosphoric acid, Acetic acid, Alumina polishing powder, Diamond polishing paste, Distilled water

8	Standard plain carbon steel samples in annealed and normalized condition
9	Standard plain carbon steel samples in hardened and tempered condition
10	White, gray, malleable and ductile cast iron samples
11	Pure copper, Brass and Tin-bronze samples
12	Al-Cu, Al-Si and Al-Mg alloy samples
13	Monel, Inconel, and Lead and Tin based Babbit alloys.samples
14	Optical camera and Image Analyzer Software

Suggested Project List:

1. Conduct a comparative study of Fe-Fe_3C and Fe-C equilibrium diagrams and analyze their significance in steel metallurgy.
2. Justify the differences in mechanical properties of three different plain carbon steels based on composition and microstructure.
3. Select a cast iron suitable for a particular engineering application and justify the selection with reasoning.
4. Estimate the microstructure and property variations in Duralumin alloy subjected to different ageing cycles.
5. Compare the suitability of lead and tin-based Babbitt alloys for various service conditions, considering mechanical and tribological properties.

Suggested Activities for Students:

1. Prepare a chart relating the carbon content of Fe-C alloys with their microstructure and mechanical properties.
2. Draw and compare the microstructures of plain carbon steels in various heat-treated conditions (annealed, normalized, hardened, tempered).
3. Deduce the microstructure of cast irons based on graphitization potential (high, medium, low) and cooling rate.
4. Compare the electrical conductivity and corrosion resistance of pure copper, brass, and tin-bronze.
5. Prepare a list of etchants and etching techniques used for metallography of Inconel 625.
6. Visit a nearby metallurgical testing laboratory to observe practical metallographic techniques and testing equipment.

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