GUJARAT TECHNOLOGICAL UNIVERSITY

Program Name: Bachelor of Engineering
Level: UG
Branch: Metallurgy
Subject Code: BE04021031
Subject Name: Physical Metallurgy

w.e.f.Academic Year:	2024-25
Semester:	4
Category of the Course:	Professional Core Course

Prerequisite:	Nil
Rationale:	**T**he metal and alloy behavior under different conditions is fundamental to materials science and engineering. The course is designed to give a thorough insight into alloy systems, phase transformation, and thermal and compositional changes and their impact on microstructure and mechanical properties. This knowledge is essential for selecting, processing, and optimizing materials for engineering applications. The course seeks to combine basic theory with industrial application to allow students to read phase diagrams, comprehend heat treatment processes, and understand the behavior of critical engineering alloys. These skills are essential for the manufacture, quality control, design, and material development roles.

Course Outcomes:

Sr. No.	CO statement	Marks % weightage
CO-1	Understand and interpret phase diagrams and alloy systems, including binary and ternary equilibrium diagrams, cooling curves, and phase transformations.	40
CO-2	Analyze the iron-carbon diagram and evaluate equilibrium phase transformations.	25
CO-3	Understand heat treatment processes & TTT and CCT diagrams for engineering applications and classify ferrous and non-ferrous alloys.	35

Teaching and Examination Scheme:

Teaching / Learning Scheme (in Hours per semester)					Total Credits	Assessment Pattern and Marks					Total Marks
						Theory		Tutorial / Practical			
L	T	P	PBL*	Total no of hours per semester		ESE (E)	PA / CA (M)	PA/CA (I)	PBL (I)	ESE (V)	
45	0	60	15	120	4	70	30	20	30	50	200

*** Problem Based Learning (PBL) aims to accommodate learning beyond syllabus as per clause 9.4 of NBA manual.**

Content:

Sr. No.	Content	Total Hrs	% Weightage
1	**Module 1:** Concepts of alloy system and explanation of terms like system, component, phase, equilibrium, degree of freedom, structural constituent of an alloy, Crystallization and solidification of metal or an alloy, cooling curves, Phase rule and phase equilibria. Phases in Alloys – like Mechanical Mixtures, Solid Solutions, Intermediate Phase. Equilibrium diagrams and their classification based on solubility of components in liquid and solid states (Isomorphous, Eutectic, Peritectic, Monotectic, Eutectoid and Peritectoid systems and various reactions, common binary systems viz. Cu-Ni, Al-Si, Cu-Sn, Al-Cu, Pb-Sn, Cu-Zn, its morphology and solidification characteristics with the distribution of phases, effect of non-equilibrium cooling on morphology. Basic understanding of Ternary diagrams of simple systems, Strengthening mechanisms.	**15**	**33**
2	**Module 2:** Allotropy of Iron, Iron-carbon diagram – Phases and micro-constituents in Fe-Fe_3C diagram, Equilibrium phase transformations, Critical temperatures, Equilibrium structures of plain carbon steels, Phase Transformation in Cast Iron. Lever rule - Analytical problems for this unit.	**14**	**31**
3	**Module 3:** Definition and objective of the Heat treatment, Introduction to Isothermal and continuous cooling transformation diagrams (TTT and CCT diagrams); Heat Treatment processes - annealing, normalizing, hardening and tempering of steels, hardenability of steel.	**08**	**18**
4	**Module 4:** Introduction to important ferrous alloys (stainless and special steels, cast irons), aluminum alloys, titanium alloys, copper base alloys.	**08**	**18**
	Total	**45**	**100**

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
20	**40**	**30**	**10**	**0**	**0**

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Note: This specification table shall be treated as a general guideline for students and teachers. The actual distribution of marks in the question paper may vary slightly from above table.

Reference Books:

1. Physical Metallurgy: Principles and Practice by V. Raghavan, Edition: 3rd Edition (2015), Publisher: PHI Learning.
2. Heat Treatment: Principles and Techniques by T.V. Rajan, C.P. Sharma, Ashok Sharma, Edition: 3rd Edition (2012), Publisher: PHI Learning.
3. Introduction to Physical Metallurgy by Sidney H. Avner, Edition: 2nd Edition, Publisher: McGraw Hill Education.
4. Physical Metallurgy Principles by Robert E. Reed-Hill, December 2008, Publisher: Affiliated East-West Press.
5. Physical Metallurgy Principles by Reza Abbaschian, Lara Abbaschian, Edition: 5th Edition (2025), Publisher: Cengage Learning.
6. Physical Metallurgy for Engineers by D.S. Clark, W.R. Varney, Publisher: CBS Publishers, Edition: 1989.
7. Principles of Metallographic Laboratory Practice by G.E. Kehl, H. Davis, Publisher: McGraw-Hill, Edition: 1996.
8. Engineering Physical Metallurgy by Y. Lakhtin, Publisher: MIR Publications, Edition: 1989.
9. Light Metals by I. J. Polmear, Publisher: Elsevier, Edition: 2005.
10. Physical Metallurgy Vol I by A.Gulyaev, Publisher: MIR Publications, Edition: 1989.
11. Material Science & Metallurgy by Dr. G. H. Upadhyay, and Prof. A. H. Dafda, Publisher: Atul Prakashan.
12. Materials Engineering by Dhreerendra Kumar Dwivedi, AICTE Book, E-kumbh, (https://ekumbh.aicte-india.org/book.php#)
13. Modern Physical Metallurgy by R.E. Smallman, Edition: 4th Edition (2013), Publisher: Elsevier.

List of Experiments:

1. Study of metallurgical microscope and dissection of its various parts.
2. Hands-on practice in metallographic sample preparation and microstructure development.
3. Analysis of the iron-iron carbide phase diagram.
4. Demonstration of standard metallographic specimens of steels, and cast iron.
5. Demonstration of standard metallographic specimens of non-ferrous metals.
6. Microstructural analysis using photo metallography and image analyzer.
7. Construction of phase diagram from given data using tie line and lever rule.
8. Measurement of grain size in metallographic specimens as per standards.

9. Identification of inclusions in metallographic specimens as per standards.
10. Examination of the effect of different quenching media on steel hardening.
11. Measurement of hardenability using jominy end quench test.
12. Study of heat treatment and microstructural changes in plain carbon steels.
13. Report on lab visit/industrial visit/expert talk/online videos.
14. Poster/chart preparation on given topics based on curriculum.

Major Equipment: Metallurgical Microscopes, Metallography Equipment, Muffle furnace, Polishing Machine, Jominy End Quench test setup, Hardness tester.

List of Open Source Software/learning website:

- https://swayam.gov.in/
- https://alison.com/course/the-basic-science-of-metallurgy
- http://ocw.mit.edu/
- https://www.doitpoms.ac.uk/

- **Activities suggested under Problem Based Learning:**

Sr. No.	Name of the activity	No. of hours	Evaluation Criteria
1.	Industry/Research laboratory visit	Visit = 5h, Report preparation = 5h Total = 10h	Based on the report submitted. Report should contain observations and calculations based on industry/ lab data.
2.	Technical Video based learning related to the subject	Duration of video = 5h Report preparation = 5h Total = 10h	Report /presentation based on the video learning outcomes.
3.	Assignment writing. Numerical based assignment is preferable.	5 assignments of 2h each. Total = 10h	Based on the assignment submitted.
4.	Expert Lecture/session	Lecture = 2 hr Report = 1 hr Total = 03 h	Based on the report submitted. Report should contain observation and learning.
5.	Self-learning on-line course	Minimum duration of the course should be 10h.	Examination based assessment at the end of course. Based on the certificate produced.
6.	Complex problem solving	Maximum 2 problems. Study of the problem and	Based on the depth of the solution submitted.

		solution finding, Total = 10h	
7	Videos on Industrial safety aspects based on subject	Duration of video = 5h Report preparation = 5h Total = 10h	Based on quiz/report submitted
8	Discussion on research paper based on relevant subject	5 research paper = 20 h	Summarize research paper and evaluation critical parameters
9.	Poster/chart/powerpoint preparation on technical topics	Duration = 6 h	Based on poster/chart preparation and presentation skills
10	Working/non-working model on technical topics	Working = 12 h Non- working = 8 h	Based on inter department/external evaluation
11	Industrial exposure for 2-3 days to observe and provide tentative solutions on society/environment/health/any other issue	Duration = 15 h for industrial exposure Problem identification and tentative solution = 10 h Max. Total Hrs. = 20 h	Based on evaluation of critical problems and solutions
12	Group Discussion on emerging/trending technical topics based on subject	Duration = 1 h each	Based on performance in group discussion, technical depth, knowledge etc.
13.	Real world case studies-based learning	Duration of data collection/study = 5h Report preparation = 5h Total = 10h	Based on in-depth study, technical depth, data collected, fact finding, etc.
14.	Online quiz or MCQ test based on curriculum.	Preparation of the content = 4 h. Quiz/Test = 1 h Total = 5 h	Based on quiz score and reflection summary.

Note:

1. All the suggested activity should be related to the subject.
2. The number of hours is suggestive. Faculty can sub-divide the number of hours based on the activity. However, the total number of hours is fixed.
3. Rubrics for the evaluation can be prepared by the faculty.

****