GUJARAT TECHNOLOGICAL UNIVERSITY

METALLURGY ENGINEERING (21)
PHYSICAL METALLURGY
SUBJECT CODE: 2152106
B.E. 5th SEMESTER

Type of course: Engineering Core

Prerequisite: Nil

Rationale: This course deals with the understanding of physical and chemical behavior of different ferrous and non ferrous metals and alloys with respect to their composition, properties and applications including phase diagrams. This course will help the student to understand the effect of alloying elements leading to modification of properties in the alloys and their applications. The course involve use of different standards for metallography. It is therefore a key course for metallurgical engineers who want to advance in this field.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks						Total Marks
L	T	P	C	Theory Marks			Practical Marks			
				ESE (E)	PA (M)		ESE (V)		PA (I)	
					PA	ALA	ESE	OEP		
4	0	2	6	70	20	10	20	10	20	150

Content:

Sr. No.	Content	Total Hrs	% Weightage
1	**Introduction** Introduction to phys met, Crystal and crystal systems, miller indices planes and direction	**4**	**6**
2	**Solidification of Metals & Alloys** Nucleation and growth phenomena, Constitutional supercooling, Eutectic solidification. Rules of formation of various types of solid solutions, Primary & Intermediate phases and their formation, Intermetallic compounds	**6**	**10**
3	**Phase Diagram** Concepts of alloy system and explanation of terms like system, component, phase, micro constituent and degree of freedom, structural constituent of an alloy, phase rule and phase equilibria, equilibrium diagrams and their classification based on solubility of components in liquid and solid states, cooling curves, morphology and distribution of phases, effect of nonequilibrium cooling on morphology. Eutectic, peritectic, monotectic, eutectoid and peritectoid reactions, binary equilibrium diagrams involving isomorphous systems and various reactions, common binary systems viz. Cu-Ni, Al-Si, Cu-Sn, Al-Cu, Pb-Sn, Cu-Zn. Lever rule. Ternary diagrams of simple systems, Analytical problems for this unit	**14**	**24**
4	**Iron-Carbon system** Allotropic changes, Iron-Iron carbide equilibrium diagram, Phases, Invariant reactions, Critical temperatures, Plain carbon steels, Slow cooling of steels, Effect of alloying elements, Effect of impurities, Property variation with microstructure, Classification of steels, Specification of steels, Physical significance of grain size: Grain size effects, Grain size designation, Grain size measurement, Corresponding standards. ASTM 112-96	**10**	**16**

5	**Steel and Cast Iron** Classification of steel, Plain carbon steel, Advantages and limitations of plain carbon steel, Effect of impurity elements on the properties of steel, Alloy steel, Purpose of alloying of steel, Functions of alloying elements in steel, Effects of alloying elements on the properties of steel, Properties and applications of various alloy steel such as stainless steel, Systems for designation of steel, Coding of steel as per Indian Standard (IS) and American Standard Classification according to graphite morphology and matrix structure, Gray, White, Ductile, Malleable, Mottled and Compacted graphite cast irons, Their properties and applications, Indian Standards applicable to cast irons	**20**	**34**
6	**Metallography** Microscopic examination, Polishing techniques for different metals and alloys, Etching and Mounting techniques, electrolytic polishing Metallurgical microscope, Macroscopic & Microscopic examination methods, Non metallic inclusions, ASTM E3-01: ASTM Designation for preparation of metallography specimen. ASTM E1558-99: electrolytic polishing, ASTM E45-05: Inclusion rating	**6**	**10**

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
10	**15**	**20**	**25**	**20**	**10**

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. Principles of Metallographic Laboratory Practice - G.E. Kehl and H. Davis [Mc.Hill]
2. Phase Diagrams in Metallurgy - F.N. Rhines.
3. Engineering Physical Metallurgy - Y. Lakhtin[MIR Publications]
4. Physical Metallurgy Vol I- I. A.Gulyaev [MIR Publications]
5. Physical Metallurgy for Engineers-D.S. Clark and W.R. Varney[CBS]
6. Modern Physical Metallurgy - R.E. Smallman[ELBS]
7. Heat Treatment Principles and Techniques - T.V. Rajan, C.P. Sharma and A. Sharma[Prentice Hall]
8. Physical Metallurgy – Peter Hansen, Cambridge University Press
9. Introduction to Physical Metallurgy, Sidney H. Avner, McGraw Hill Book Co. 11.
10. Metallography Techniques: principles and practice, Vander Voort, George F., McGraw-Hill Book,
11. Physical Metallurgy Principles - R.E. Reed Hill [East - West]

Course Outcome:

After learning the course the students should be able to:

i. Distinguish between metals and alloys
ii. Explain transformation for various carbon percentages
iii. Relate Carbon, microstructure and mechanical properties
iv. Distinguish different types of stainless steel with reference to composition, microstructure, properties, and applications.
v. Compare different types of Copper alloys based on properties and applications
vi. Use standards for metallography.

List of Experiments:

1. Study of metallurgical microscope.
2. Study of steps of metallic specimen for microscopic examination.

3. Study Iron-Iron Carbide phase diagram.
4. Study of standard metallographic specimen of steels.
5. Study of standard metallographic specimen of Cast Iron.
6. Study of standard metallographic specimen of Non Ferrous Metals and Alloys.
7. Prepare and observe metallographic specimen of given steel sample.
8. Microstructure analysis by Image analysis and Photo metallography.
9. Draw equilibrium diagram for given data and apply Tie line and Lever Rule.
10. For given metallographic specimen measure grain size and identify Inclusions as per standard.

Design based Problems (DP)/Open Ended Problem: Not Recommended

Major Equipment:

i. Metallurgical Microscope
ii. Standard specimens
iii. Polishing disc machine to prepare specimens with necessary consumables.
iv. Emery papers, etching reagents
v. Image Analysis System
vi. Cutting machine
vii. Grinder

List of Open Source Software/learning website:

1. http://nptel.iitm.ac.in/courses.php?disciplineId=113
2. http://www.sv.vt.edu/classes/MSE2094_NoteBook/96ClassProj/examples/kimco n.html
3. http://www.youtube.com/watch?v=IskiZaGDQow
4. http://ocw.mit.edu/courses/index.htm#materials-science-and-engineering

ACTIVE LEARNING ASSIGNMENTS: Preparation of power-point slides, which include videos, animations, pictures, graphics for better understanding theory and practical work – The faculty will allocate chapters/ parts of chapters to groups of students so that the entire syllabus to be covered. The power-point slides should be put up on the web-site of the College/ Institute, along with the names of the students of the group, the name of the faculty, Department and College on the first slide. The best three works should submit to GTU.