GUJARAT TECHNOLOGICAL UNIVERSITY, AHMEDABAD, GUJARAT

Competency-focused Outcome-based Green Curriculum-2021 (COGC-2021)
Semester-III

Course Title: Physical Metallurgy-II
(Course Code: 4332102)

Diploma Programme in which this course is offered	Semester in which offered
Metallurgy Engineering	Third

1. RATIONALE

A metallurgical engineer must possess the basic knowledge of structure-property relationship of various metallic materials for alloy development, process design and material selection purposes. This course deals with the understanding of physical behavior of different ferrous and non-ferrous metals and alloys with respect to their phase diagram, composition, microstructure, properties and applications. The course shall help the students to understand the effect of alloying elements leading to modification of properties in the alloys and their applications.

2. COMPETENCY

The course content should be taught and curriculum should be implemented with the aim to develop different skills in the student so that they are able to acquire following competency:

- **Use the principles of physical metallurgy for ferrous and non-ferrous metals and alloys to identify and apply them as per the need with respect to composition and properties.**

3. COURSE OUTCOMES (COs)

The theory should be taught and practical should be performed in such a manner that students are able to acquire different learning outcomes in cognitive, psychomotor and affective domain to demonstrate following course outcomes.

i. Draw the Fe-Fe_3C equilibrium diagram and calculate various phases present at different carbon content and temperature.
ii. Classify steels and relate their composition and microstructure with their properties as well as applications.
iii. Distinguish the types of cast iron on the basis of their composition, microstructure, properties and applications.
iv. Explain the phase diagram, composition, microstructure, properties and applications of copper alloys and aluminum alloys.
v. Describe the composition, microstructure, properties and uses of nickel alloys and babbitt alloys.

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme (In Hours)			Total Credits (L+T+P/2)	Examination Scheme				
				Theory Marks		Practical Marks		Total Marks
L	T	P	C	CA	ESE	CA	ESE	
3	0	4	5	30*	70	50	50	200

(*): Out of 30 marks under the theory CA, 10 marks are for assessment of the micro- project to facilitate integration of COs and the remaining 20 marks is the average of 2 tests to be taken during the semester for the assessing the attainment of the cognitive domain UOs required for the attainment of the COs.

***Legends: L**-Lecture; **T**– Tutorial/Teacher Guided Theory Practice; **P** -Practical; **C** – Credit; **CA** - Continuous Assessment; **ESE** -End Semester Examination.*

5. SUGGESTED PRACTICAL EXERCISES

The following practical outcomes (PrOs) are the sub-components of the COs. Some of the **PrOs** marked **'*'** are compulsory, as they are crucial for that particular CO at the 'Precision Level' of Dave's Taxonomy related to 'Psychomotor Domain'.

Sr. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
1	Draw and label Fe-Fe_3C equilibrium diagram. State various invariant reactions and critical temperatures.	I	04
2	Apply lever rule for given carbon percentage for hypoeutectoid, eutectoid and hypereutectoid steels.	I	04
3	Prepare the metallographic specimen of steel for microscopic examination and observe the microstructure.	II	10
4	Observe the microstructure of standard plain carbon steel samples in annealed and normalized condition under metallurgical microscope.	II	04
5	Observe the microstructure of standard plain carbon steel samples in hardened and tempered condition under metallurgical microscope.	II	04
6	Observe and compare the microstructures of different types of cast irons under metallurgical microscope.	III	04
7	Draw and label binary phase diagrams of copper and aluminum alloys.	IV	04
8	Identify and distinguish distinct features of microstructure of pure Copper, Brass and Tin-Bronze.	IV	04
9	Study distinct features of microstructure of Aluminum and its alloys.	IV	04

10	Identify the microconstituents of Monel, Inconel 625 and Hastealloy C.	V	04
11	Observe the microstructure of Lead and Tin based Babbit alloys.	V	04
12	Determine the grain size and volume fraction of microconstituents by image analyzer as per I.S. code.	I	06
Total Hours			**56**

Note:

i. *More **Practical Exercises** can be designed and offered by the respective course teacher to develop the industry relevant skills/outcomes to match the COs. The above table is only a suggestive list of practical.*

ii. *The following are some **sample** 'Process' and 'Product' related skills (more may be added/deleted depending on the course) that occur in the above listed **Practical Exercises** of this course required which are embedded in the COs and ultimately the competency.*

Sr. No.	Sample Performance Indicators for the PrOs	Weightage in %
1	Identification of equipment/tools/setup/materials required for the experiment.	20
2	Execution of the experiment, observation and recording of result.	20
3	Interpretation of result and drawing of conclusions.	20
4	Active participation and response to the questions asked regarding the experiment.	10
5	Safety measures and good housekeeping.	10
6	Submission of the report in time and attendance.	20
Total		**100**

6. MAJOR EQUIPMENT/ INSTRUMENTS/SOFTWARE/MATERIAL REQUIRED

The major equipment/instruments/software/material required to develop PrOs are given below with broad specifications to facilitate their procurement by the administrators/management of the institutes

Sr. No.	Equipment Name with Broad Specifications	PrO No.
1	Metallurgical Microscope (up to 1000X magnification)	3-6,8-12
2	Bench vise, Manual Hacksaw and HSS hacksaw blade	3-6,8-12
3	Cold mounting molds	3-6,8-12
4	Wheel Grinder and Belt Grinder	3-6,8-12
5	Emery Papers (120, 220, 320, 400, 600, 800, 1000, 1200, 1500, 2000, 3000 grit)	3-6,8-12
6	Double Disc Polishing Machine, Electrolytic polishing and etching machine	3-6,8-12
7	Chemicals – Epoxy resin, LR grade of Nitric acid, Ethanol, Picric acid, Iron(III) chloride, hydrochloric acid, hydrofluoric	3-6,8-12

	acid, phosphoric acid, acetic acid, alumina polishing powder, diamond polishing paste and distilled water	
8	Standard plain carbon steel samples in annealed and normalized condition	4
9	Standard plain carbon steel samples in hardened and tempered condition	5
10	White, gray, malleable and ductile cast iron samples	6
11	Pure copper, Brass and Tin-bronze samples	8
12	Al-Cu, Al-Si and Al-Mg alloy samples	9
13	Monel, Inconel 625 and Hastealloy C samples	10
14	Lead and Tin based Babbitt alloy samples	11
15	Optical camera and Image Analyzer Software	12

7. AFFECTIVE DOMAIN OUTCOMES

The following sample Affective Domain Outcomes (ADOs) are embedded in many of the above- mentioned COs. More could be added to fulfill the development of this course competency.

i. Contribute to the society and environment by selecting a high quality, cost-effective and ecofriendly metal or alloy for a particular application.
ii. Conserve the natural mineral deposits by using the alloying elements judiciously.
iii. Follow ethical practices while selecting a metal or alloy for any application considering the safety of life and property.

8. UNDERPINNING THEORY

The major underpinning theory is given below based on the higher level UOs of Revised Bloom's taxonomy that are formulated for development of the COs and competency. If required, more such UOs could be included by the course teacher to focus on attainment of COs and competency.

Unit	Major Learning Outcomes	Topics and Sub-topics
Unit – I Iron-Iron Carbide Equilibrium Diagram	1.a. Explain the allotropy of iron 1.b. Draw and label Fe-Fe_3C equilibrium diagram 1.c. State the invariant reactions and critical temperatures 1.d. Identify the phases / microconstituents of Fe-C alloys 1.e. Apply lever rule in Fe-Fe_3C diagram 1.f. Relate carbon content of Fe-C alloys with their microstructure and mechanical properties	1.1. Allotropy of iron 1.2. Fe-Fe_3C equilibrium diagram 1.3. Invariant reactions and critical temperatures 1.4. Definition of phases / microconstituents and their mechanical properties 1.5. Application of lever rule in Fe-Fe_3C diagram 1.6. Relation between carbon content, microstructure and mechanical properties of Fe-C alloys
Unit – II Steels	2.a. Define and classify steels 2.b. Describe the phase transformation and microstructure of any plain carbon steel in equilibrium cooling condition 2.c. Explain the mechanism of austenite to pearlite and austenite to martensite transformation 2.d. Relate the composition and microstructure of plain carbon steels with their properties and applications	2.1. Definition and classification of steels 2.2. Phase transformation and microstructure of slowly cooled plain carbon steels 2.3. Mechanism of austenite to pearlite and austenite to martensite transformation in plain carbon steels 2.4. Properties and applications of plain carbon steels
Unit – III Cast Irons	3.a. Define and classify cast irons 3.b. Describe the phase transformation and microstructure of white cast iron 3.c. Relate the composition and microstructure of different types of cast irons with their properties and applications	3.1. Definition and classification of cast iron 3.2. Phase transformation and microstructure of white cast iron 3.3. Composition, microstructure, properties and applications of white, gray, malleable and ductile cast iron

Unit – IV Copper and Aluminum Alloys	4.a. State the properties of pure copper and aluminum 4.b. Draw and label the binary phase diagram of Cu-Zn, Cu-Sn, Al-Cu, Al-Si and Al-Mg 4.c. Classify copper and aluminum alloys 4.d. Interpret the information about composition and microstructure of copper and aluminum alloys to deduce their properties and applications	4.1. Properties of pure copper and aluminum 4.2. Binary phase diagram of Cu-Zn, Cu-Sn, Al-Cu, Al-Si and Al-Mg 4.3. Classification of copper and aluminum alloys 4.4. Composition, microstructure, properties and applications of Cu-Zn and Cu-Sn alloys 4.5. Composition, microstructure, properties and applications of Al-Cu, Al-Si and Al-Mg alloys
Unit -V Special Non-Ferrous Alloys	5.a. State the properties of pure nickel, lead and tin 5.b. Classify nickel and babbitt alloys 5.c. Employ the knowledge of composition and microstructure of Monel, Inconel 625, Hastealloy C to understand their properties and applications 5.d. Relate the composition and microstructure of lead and tin based babbitts with their properties and applications	5.1. Properties of pure nickel, lead and tin 5.2. Classification of nickel and babbitt alloys 5.3. Composition, microstructure, properties and applications of Monel, Inconel 625, Hastealloy C 5.4. Composition, microstructure, properties and applications of lead and tin based babbitts

9. SUGGESTED SPECIFICATION TABLE FOR QUESTIONPAPER DESIGN

Unit	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	Iron-Iron carbide equilibrium diagram	08	6	8	6	20
II	Steels	10	6	10	6	22
III	Cast Irons	08	6	7	7	20
IV	Copper and aluminum alloys	10	8	9	7	24
V	Special non-ferrous alloys	06	4	5	5	14
Total		**42**	**30**	**39**	**31**	**100**

Legends: *R = Remember; U = Understand; A = Apply and above levels (Bloom's revised*

taxonomy)

Note:

1. *This specification table shall be treated as a general guideline for students and Teachers. The actual distribution of marks in the question paper may slightly vary from above table.*
2. *Ask the questions from each topic as per marks weightage. Numerical questions are to be asked only if it is specified. Optional questions must be asked from the same topic.*

10. SUGGESTED STUDENT ACTIVITIES

Other than the classroom and laboratory learning, following are the suggested student-related co-curricular activities which can be undertaken to accelerate the attainment of the various outcomes in this course: Students should conduct following activities in group

1. Prepare a chart relating the carbon content of Fe-C alloys with their microstructure and properties.
2. Draw and compare the microstructure of plain carbon steels in various heat treated condition.
3. Deduct the microstructure of cast iron depending upon high, medium and low graphitization potential as well as cooling rate.
4. Compare the electrical and corrosion resistance of pure copper, brass and tin-bronze.
5. Prepare a list of etchants and etching techniques for metallography of Inconel 625.
6. Visit nearby metallurgical testing laboratory.

11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

Sr. No.	Unit Title	Strategies
1	Structure of Crystalline Solids	• Movies/Animations on phase transformations. • Interactive session with a R&D expert of alloy manufacturing industry. • Case studies.
2	Imperfection in Solids	
3	Solidification of Metals and Alloys	
4	Equilibrium Diagrams	
5	Metallography	

12. SUGGESTED MICRO-PROJECTS

Only one micro-project is planned to be undertaken by a student that needs to be assigned to him/her in the beginning of the semester. In the first four semesters, the micro-project are group-based. However, in the fifth and sixth semesters, it should be preferably be individually undertaken to build up the skill and confidence in every student to become problem solver so that s/he contributes to the projects of the industry. In special situations where groups have to be formed for micro-projects, the number of students in the group should not exceed three.

The micro-project could be industry application based, internet-based, workshop-based, laboratory-based or field-based. Each micro-project should encompass two or more COs which are in fact, an integration of PrOs, UOs and ADOs. Each student will have to maintain

dated work diary consisting of individual contribution in the project work and give a seminar presentation of it before submission. The total duration of the micro- project should not be less than 16 (sixteen) student engagement hours during the course. The student ought to submit micro-project by the end of the semester to develop the industry oriented COs.

A suggestive list of micro-projects is given here. This has to match the competency and the COs. Similar micro-projects could be added by the concerned course teacher:

1. Comparative study of Fe-Fe_3C and Fe-C equilibrium diagrams.
2. Justify the difference in mechanical properties of three different plain carbon steels.
3. Select a cast iron suitable for a particular application and justify the selection.
4. Estimate the microstructure and property variation in Duralumin alloy with different ageing cycles.
5. Compare the suitability of lead and tin babbitts for different service conditions.

13. SUGGESTED LEARNING RESOURCES

Sr. No.	Title of Book	Author	Publication with place, year and 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

14. SOFTWARE/LEARNING WEBSITES

1. https://nptel.ac.in/courses/113105023
2. https://ocw.mit.edu/courses/3-40j-physical-metallurgy-fall-2009/
3. https://www.georgevandervoort.com/metallography/
4. https://www.doitpoms.ac.uk/miclib/browse.php?cat=1&list=mic
5. https://www.youtube.com/watch?time_continue=44&v=5cpdJ3IGGDc&feature=emb_title

15. PO-COMPETENCY-CO MAPPING

Semester II	Physical Metallurgy-II (Course Code:4332102)						
	POs						
Competency & Course Outcomes	PO 1 Basic & Discipline specific knowledge	PO 2 Problem Analysis	PO 3 Design/ development of solutions	PO 4 Engineering Tools, Experimen-tation& Testing	PO 5 Engineering practices for society, sustainability & environment	PO 6 Project Manage-ment	PO 7 Life-long learning
Competency	**Use the principles of physical metallurgy for ferrous and non-ferrous metals and alloys to identify and apply them as per the need with respect to composition and properties.**						
CO1. Draw the Fe-Fe_3C equilibrium diagram and calculate various phases present at different carbon content and temperature.	3	2	2	-	-	-	1
CO2. Classify steels and relate their composition and microstructure with their properties as well as applications.	3	3	2	2	-	-	1
CO3. Distinguish the types of cast iron on the basis of their composition, microstructure, properties and applications.	3	3	2	2	-	-	1
CO4. Explain the phase diagram, composition, microstructure, properties and applications of copper alloys and aluminum alloys	3	3	2	2	-	-	1
CO5. Describe the composition, microstructure, properties and uses of nickel alloys and babbitt alloys.	2	2	1	2	-	-	1

Legend: *'3' for high, '2' for medium, '1' for low or '-' for the relevant correlation of each competency, CO, with PO/ PSO*

16. COURSE CURRICULUM DEVELOPMENT COMMITTEE

GTU Resource Persons

S. No.	Name and Designation	Institute	Contact No.	Email
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