SECOND SEMESTER 2020-21
COURSE HANDOUT

Date: 16.01.2021

In addition to part I (General Handout for all courses appended to the Time table) this portion gives further specific details regarding the course.

Course No	:	**CHE F 243**
Course Title	:	**Materials Science and Engineering**
Instructor-in-Charge	:	**Krishna Etika**
Tutorial Instructor(s)	:	**Priya C. Sande/S. Anil Kumar**
Lecture	:	**TTh 4th Hour (11:00 A.M.) W 10th Hour (5:00 P.M)**
Tutorial	:	**F 1st Hour (08:00 A.M.)**

1. Course Description:

Introduction on materials for engineering, structures of metals, ceramics and polymers; crystalline structure imperfections; amorphous and semi crystalline materials (includes glasses, introduction to polymers); Correlation of structure to properties and engineering functions (mechanical, chemical, electrical, magnetic and optical); phase diagrams; Improving properties by controlled solidification, diffusion or heat treatment; Failure analysis and non-destructive testing; Types of materials (includes synthesis, fabrication and processing of materials): Polymers and composites, Environmental degradation of materials (corrosion); Evolution of materials (functional materials, Biomimetic materials, energy saving materials etc); Criteria for material selection

2. Scope and Objective of the Course:

This course will be focused on the necessity of the chemical engineering students to know and understand about the materials used in industrial applications and develop a background in the general area of materials. Systematic review of the basic structures of inorganic solids (metallic, ceramics, and polymers) and techniques to determine basic microstructures and phases will be done. Emphasis will be given on structures-properties correlations, and applications in chemical industries. Advance materials and their applications will be covered.

3. Text Book(s):

T1. Callister's Materials Sc & Engg, W.D. Callister & R. Balasubramaniam (Adapted), Wiley, 2nd. ed., 2014.

4. Reference Books:

R1. Materials science and engineering by V. Raghavan, 5th edition, Prentice Hall of India, ISBN: 978-81-203-2455-8

R2. Materials science and engineering by Smith, Hashemi, and Prakash, 4th edition (2008), Tata McGraw Hill education pvt. Limited, ISBN 10: 0-07-066717-9 or ISBN 13: 978-0-07-066717-4.

R3. The Science and Engineering of Materials by Askeland and Fulay, 6th Ed. Cengage Learning, Indian reprint 2012, ISBN 9788131516416.

R4. Essentials to Materials Science and Engineering by Askeland and Phule, 2nd Ed. Cengage Engineering, Indian reprint 2013, ISBN: 9788131520703

5. Course Plan:

Module No: Topics	Topics details to be Covered in Lecture (L) & Tutorial (T) Sessions	Reference Ch.:Sec.	Learning Outcome
M1: Introduction to Engineering Materials, properties, application	**L1:** Why Study Materials Science and Engineering? Classification of Materials	T1:1	At the end of the module, the student will be able to • Summarize the scope, objectives, and structure of course • Recognize the Importance of materials in chemical engineering and related applications
M2: Crystal Structures, Crystallographic Points, Directions, and Planes, Crystalline and Noncrystalline Materials	**L2**: Unit cell, Crystallographic directions and planes. Point Coordinates, Crystallographic Directions, Crystallographic Planes	T1:3.1-3.10	At the end of the module, the student will be able to • Distinguish between crystalline and amorphous materials. • Identify crystal structures, direction and planes.
	L3: Single Crystals, Polycrystalline Materials, Anisotropy, Crystal Structures, Noncrystalline Solids	T1:3.1-3.10	
	T1. Exercise problems	T1: 3	
M3: Structures of materials (Metals, Ceramics and Polymers).	**L4:** FCC, BCC, HCP, Density Computation, Closed pack crystal structure, Polymorphosm & Allotropy,	T1 4.1-4.9	At the end of the module, the student will be able to • Draw unit cells for SC, FCC, BCC and HCP crystal structures • Compute density of metals and ceramics given their unit cell dimensions • Predict the crystal structure of ceramics. • Describe basic polymer molecule structure • Calculate number average molecular weights and degree of polymerization for a specified polymer. • Describe the working
	L5: Radius ratio rules, AX-Type, A_MX_P-Type, and $A_MB_NX_P$-Type Crystal Structures, Ceramic Density Computations, Silicate Ceramics and Carbon.	T1 4.10-4.17	
	L6: Polymer molecules, Molecular Weight, Shape, Structure, and Configurations, Thermoplastic and Thermosetting Polymers, Copolymers, Crystallization, Melting, and glass transition in polymers.	T1 13.1-13.10 T1 14.10-14.13	
	T 2 : Exercise Problems	T1 4, 13, 14.	

	L7: Polymer crystallinity, Polymer crystals, polymer types **L8-9. :** Determination of crystal structure, Bragg's Law, diffraction technique, Optical and electron microscopy, grain size determination	T1 4.20, T1 5.11-5.13 + notes	principle of XRD & Microscopic techniques work for Materials Characterization
	T3. Exercise problems	T1: 4, 5	
M5: Imperfections in Solids, Point Defects, Miscellaneous Imperfections	**L10:** Vacancies and Self-Interstitials, Impurities in Solids, Specification of Composition	T1: 5.1-5.10	At the end of the module, the student will be able to • Describe defects in crystal structures of metals and ceramics. • Identify edge,screw and dislocation type of defects • Name various ionic point defects in ceramics
	L11-12: Dislocations–Linear Defects, Interfacial Defects, Bulk or Volume Defects, Atomic Vibrations	T1: 5.1-5.10	
	T4. Exercise problems	T1: 5	
M6: Diffusion Steady and non-steady diffusion	**L12:** Diffusion Mechanisms, Steady-State Diffusion,	T1: 6.1-6.8	At the end of the module, the student will be able to • Describe the atomic mechanism of diffusion in metallic, ionic and polymeric materials • Calculate the diffusion coefficient for some materials at a specified temperature. • Write Fick's First and Second Law for diffusion
	L13-14: Nonsteady-State Diffusion, Factors That Influence Diffusion, Other Diffusion Paths		
	T5. Exercise problems	T1: 5	
M7: Mechanical properties and Failure of materials	**L15:** Concept of stress and strain, elastic deformation, plastic deformation, hardness, Viscoelastic deformation, Factors influencing mechanical properties	T1: 9.5-9.10 T1:	At the end of the module, the student will be able to • State Hooke's • Perform basic calculations on engineering stress strain diagram • Describe the mechanism of fracture in engineering materials and perform
	L16-17: Ductile and Brittle fracture, fracture mechanics, Impact facture testing, Fatigue and Creep Fracture.	T1:11.1-11.14	
	T6. Exercise problems	T1: 9, 11	

	L 18: Fracture of polymers, Factors that influence mechanical properties of semi crystalline polymers, Deformation of Elastomers	T1: 14.5-14.9	basic calculations. • Define creep and fatigue and the conditions under which they occur. • List the factors influencing mechanical properties of materials.
M 8: Dislocations and Strengthening Mechanisms	**L19**: Characteristics of Dislocations , Slip Systems , Slip in Single Crystals , Plastic Deformation of Polycrystalline Materials , Deformation by Twinning	T1: 10.1-10.7	At the end of the module, the student will be able to • Describe edge and screw dislocation motion from an atomic perspective • Define slip system and cite one example • Define and explain the phenomenon of strain hardening in terms of dislocations and strain field interactions.
	L20-21: Strengthening by Grain Size Reduction, Solid-Solution Strengthening, Strain Hardening, Recovery, Recrystallization, Grain growth and Precipitation Hardening	10.8-10.14	
	T7. Exercise problems	T1: 10,14	
M9: **Phase Diagrams**	**L22:** Solubility Limit, Phases, Microstructure, Phase Equilibria, One-Component (or Unary) Phase Diagrams. Binary Isomorphous Systems, Development of Microstructure in Isomorphous Alloys, Binary Eutectic Systems,	T1: 7.1-7.10	At the end of the module, the student will be able to • Schematically sketch simple phase diagrams and locate various phase regions in the diagram. • Identify phases present in a binary phase diagrams • Locate temperatures and compositions of all eutectic, eutectoid, peritectic and congruent phase transformations • Write reactions for all these transformations for either heating or cooling • Given the composition of an iron-carbon alloy, identify whether the alloy is hypo or hyper eutectoid and compute mass fraction of the phases.
	L23-24: Development of Microstructure in Eutectic Alloys, Equilibrium Diagrams Having Intermediate Phases or Compounds, Eutectic and Peritectic Reactions, The Gibbs Phase Rule, The Iron–Iron Carbide (Fe–Fe_3C) Phase Diagram, Development of Microstructure in Iron–Carbon Alloys, The Influence of Other Alloying Elements.	T1: 7.10-7.20	
	T8. Exercise problems	T1: 7	

M 10: **Phase Transformations**	**L25:** Kinetics of phase transformations, Metastable Vs equilibrium states, Isothermal Transformation Diagrams.	T1: 8.1-8.5	At the end of the module, the student will be able to • Make a schematic fraction transformation Vs logarithm of time plot for a typical solid-solid transformation and cite the equation that describes this behavior • Design a heat treatment that will produce a specified microstructure for a given isothermal transformation diagram.
	L26-28: Continuous Cooling transformations, Mechanical behavior of Fe-C alloys, tempered Martensite.	T1: 8.6-8.9	
	T9. Exercise problems	T1: 8	
M11: Composite Materials	**L 29**: Particle Reinforced Composites: Large-particle composites, concrete, Portland cement concrete, reinforced concrete, Dispersion strengthened composites. **L 30-31**: Fiber reinforced composites: Influence of fiber length, fiber orientation and fiber concentration, **L32**: Polymer Matrix Composites, Metal Matrix Composites, Ceramic Matrix Composites, **L33:** Carbon-carbon composites Hybrid Composites and Structural composites: Laminar composites, sandwich panels, nanocomposites.	T1:15.1-15.14	At the end of the module, the student will be able to • Name the three main divisions of composite materials, and cite the distinguishing feature of each. • Calculate longitudinal modulus and longitudinal strength for an aligned and continuous fibrous composites. • Cite the desirable features of metal matrix and ceramic matrix composites. • Name and briefly describe the two sub classifications of structural composites.
	T9. Exercise problems	T1: 15	
M12: Electrical properties	**L34:** Electrical conduction, ohms law, energy band structure in solids Dielectric behavior	T1 17.1-17.9	At the end of the module, the student will be able to • Describe band structure of solid materials • Calculate electrical conductivity of metals, semiconductors and
	L35: Semiconductivity, Electrical conduction in ionic ceramics and in polymers,	T1:17.10:17.17	

	L36: Dielectric behavior of materials	T1: 17:18-17.23	insulators • Define dielectric constant in terms of permittivities.
	T10. Exercise problems	T1: 17	
M13: Magnetic Properties of Materials	**L37:** Basic Concepts, Origin of magnetism in materials, Dia and Paramagnetic materials, Ferromagnetic materials.	T1: 18.1-18.4	At the end of the module, the student will be able to • Explain the nature and source of magnetism in materials • Describe magnetic hysteresis and explain why some materials may become permanent magnets.
	L38-39: Antiferromagnetic materials, Ferrimagnetic materials, Domains and hysteresis, soft and hard magnetic materials,	T1: 18.5-18.10	
	T11. Exercise problems	T1: 18	
M14: **Thermal Properties of Materials**	**L40**: Heat capacity, thermal expansion, thermal conductivity, thermal stresses,	T1:19.1-19.5	At the end of the module, the student will be able to • Explain the nature of optical interactions of materials. • Define heat capcity and thermal conductivity of materials
	T12. Exercise problems	T1: 19	
HOME READING: Materials Selection & Design Considerations, Corrosion and Degradation of Materials	Automotive Valve Spring, Materials Selection for a Torsionally Stressed Cylindrical Shaft, Artificial Total Hip Replacement, Materials for Integrated Circuit Packages, Corrosion of Metals, Corrosion of Ceramics, Degradation of Polymers	**CD 22, T1 16**	At the end of the module, the student will be able to define the criteria for the selection of materials for industrial applications using materials performance index. Life, cost and properties and the corrosion aspects of materials

6. Evaluation Scheme:

Component	Duration (min)	Weightage (Marks)	Date & Time	Nature of component (Close Book/ Open Book)
Mid-Semester Test	**90**	**90**	<TEST_1>	**OB**
Comprehensive Exam	**120**	**120**	<TEST_C>	**OB**
Quizzes (Best 5 out of 7)	**15**	**75**		**OB**
Assignment#		**15**		**OB**
Total (Marks)		**300**		

#Assignment will be take home and details of it will be announced in the class.

7. Online Consultation Hour: Friday 3-4 p.m.

8. Notices: The notices will be displayed on the Chemical Engineering Group notice board and/or Nalanda and/or emailed to your official BITS e-mail account only.

9. Make-up Policy: Make-up will be granted for genuine cases only. In the case of medical issues, certificate from authenticated doctor of the Birla Medical Center must accompany make-up application (*only prescription or vouchers for medicines will not be sufficient*). Prior permission of IC is compulsory for non-emergency cases.

- Due to the surprise nature of the Quizzes, no make-up will be granted for these.

10. Note (if any): ***The material/lecture slides (if any) provided to the students registered in this course is for academic purpose only and is considered intellectual property of BITS Pilani. These materials should not be uploaded to any external websites/forums without the permission of the Instructor.***

Krishna Etika
Instructor-in-charge
Course No. CHE F243