| Course code | Course Name | L-T-P-Credits | Year of Introduction |
|---|---|---|---|
| ME309 | METALLURGY AND MATERIALS SCIENCE | 3-0-0-3 | 2016 |

**Prerequisite : Nil**

**Course Objectives:**

- To provide physical concepts of atomic radius, atomic structure, chemical bonds, crystalline and non-crystalline materials and defects of crystal structures, grain size, strengthening mechanisms, heat treatment of metals with mechanical properties and changes in structure
- To makee aware of the behavior of materials in engineering applications and select the materials for various engineering applications.
- To understand the causes behind metal failure and deformation
- To determine properties of unknown materials and develop an awareness to apply this knowledge in material design

**Syllabus**

Chemical bonds – crystallography- imperfections- crystallization- diffusion- phase diagrams-heat treatment – strengthening mechanisms- hot and cold working – alloying- ferrous and non ferrous alloys- fatigue-creep- basics, need, properties and applications of modern engineering materials.

**Expected outcome:**

The students will be able to

i. Identify the crystal structures of metallic materials.
ii. Analyze the binary phase diagrams of alloys Fe-Fe3C, etc.
iii. Correlate the microstructure with properties, processing and performance of metals.
iv. Recognize the failure of metals with structural change.
v. Select materials for design and construction.
vi. Apply core concepts in materials science to solve engineering problems.

**Text Books**


1. Jose S and Mathew E V, Metallurgy and Materials Science, Pentagon, 2011
2. Raghavan V, Material Science and Engineering, Prentice Hall,2004


**References**


1. Anderson J.C. *et.al.*, Material Science for Engineers,Chapman and Hall,1990
2. Avner H Sidney, Introduction to Physical Metallurgy, Tata McGraw Hill, 2009
3. Callister William. D., Material Science and Engineering, John Wiley, 2014
4. Clark and Varney, Physical metallurgy for Engineers, Van Nostrand,1964
5. Dieter George E, Mechanical Metallurgy, Tata McGraw Hill,1976
6. Higgins R.A. - Engineering Metallurgy part - I – ELBS,1998
7. Myers Marc and Krishna Kumar Chawla, Mechanical behaviour of materials, Cambridge University press,2008
8. Reed Hill E. Robert, Physical metallurgy principles, 4th Edn. Cengage Learning, 2009
9. Van Vlack -Elements of Material Science - Addison Wesley,1989
10. http://nptel.ac.in/courses/113106032/1
11. http://www.myopencourses.com/subject/principles-of-physical-metallurgy-2
12. http://ocw.mit.edu/courses/materials-science-and-engineering/3-091sc-introduction-tosolid- State-chemistry-fall-2010/syllabus/
13. http://www.msm.cam.ac.uk/teaching/partIA.php

| COURSE PLAN | | | |
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| **Module** | **Contents** | **Hours** | **End Sem. Exam Marks** |
| **I** | Earlier and present development of atomic structure; attributes of ionization energy and conductivity, electronegativity and alloying; correlation of atomic radius to strength; electron configurations; electronic repulsion Primary bonds: - characteristics of covalent, ionic and metallic bond: attributes of bond energy, cohesive force, density, directional and non-directional and ductility, properties based on atomic bonding:- attributes of deeper, energy well and shallow energy well to melting, temperature, coefficient of thermal expansion - attributes of modulus of elasticity in metal cutting process – Secondary bonds:- classification- hydrogen bond and anomalous behavior of ice float on water, application- atomic mass unit and specific heat, application. *(brief review only, no Universityquestions and internal assessment from these portions.)* | **2** | **15%** |
| | Crystallography:- Crystal, space lattice, unit cell- BCC, FCC, HCP structures - short and long range order – effects of crystalline and amorphous structure on mechanical properties. | 1 | |
| | Coordination number and radius ratio; theoretical density; simple problems - Polymorphism and allotropy. | 1 | |
| | Miller Indices: - crystal plane and direction (brief review) - Attributes of miller indices for slip system, brittleness of BCC, HCP and ductility of FCC - Modes of plastic deformation: - Slip and twinning. | 1 | |
| | Schmid's law, equation, critical resolved shear stress,correlation of slip system with plastic deformation in metals and applications. | 1 | |
| **II** | Mechanism of crystallization:Homogeneous and heterogeneous nuclei formation, under cooling, dendritic growth, grain boundary irregularity. | 1 | 15% |
| | Effects of grain size, grain size distribution, grain shape, grain orientation on dislocation/strength and creep resistance - Hall - Petch theory, simple problems | 1 | |
| | Classification of crystal imperfections: - types of dislocation – effect of point defects on mechanical properties - forest of dislocation, role of surface defects on crack initiation. | 1 | |
| | Burgers vector –dislocation source, significance of Frank Read source in metals deformation - Correlation of dislocation density with strength and nano concept, applications. | 1 | |
| | Significance high and low angle grain boundaries on dislocation – driving force for grain growth and applications during heat treatment. | 1 | |
| | Polishing and etching to determine the microstructure and grain size. | 1 | |
| | Fundamentals and crystal structure determination by X – ray diffraction, simple problems –SEM and TEM. | 1 | |
| | Diffusion in solids, Fick’s laws, mechanisms, applications of diffusion in mechanical engineering, simple problems. | 1 | |
| **FIRST INTERNAL EXAMINATION** | | | |

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| **III** | Phase diagrams: - Limitations of pure metals and need of alloying - classification of alloys, solid solutions, Hume Rothery`s rule - equilibrium diagram of common types of binary systems: five types. | 2 | 15% |
| | Coring - lever rule and Gibb`s phase rule - Reactions: monotectic, eutectic, eutectoid, peritectic, peritectoid. | 1 | |
| | Detailed discussion on Iron-Carbon equilibrium diagram with microstructure and properties changes in austenite, ledeburite, ferrite, cementite, special features of martensite, transformation, bainite, spheroidite etc. | 1 | |
| | Heat treatment: - Definition and necessity – TTT for eutectoid iron–carbon alloy, CCT diagram, applications - annealing, normalizing, hardening, spheroidizing. | 1 | |
| | Tempering:- austermpering, martempering and ausforming- Comparative study on ductility and strength with structure of pearlite, bainite, spherodite, martensite, tempered martensite and ausforming. | 1 | |
| | Hardenability, Jominy end quench test, applications- Surface hardening methods:- no change in surface composition methods :- Flame, induction, laser and electron beam hardening processes- change in surface composition methods :carburizing and Nitriding; applications. | 2 | |
| **IV** | Types of Strengthening mechanisms: - work hardening, equation - precipitation strengthening and over ageing- Dispersion hardening. | 1 | 15% |
| | Cold working: Detailed discussion on strain hardening; recovery; re-crystallization, effect of stored energy; re-crystallization temperature - hot working, Bauschinger effect and attributes in metal forming. | 1 | |
| | Alloy steels:- Effects of alloying elements on steel: dislocation movement, polymorphic transformation temperature, alpha and beta stabilizers, formation and stability of carbides, grain growth, displacement of the eutectoid point, retardation of the transformation rates, improvement in corrosion resistance, mechanical properties | 1 | |
| | Nickel steels, Chromium steels etc. - Enhancement of steel properties by adding alloying elements: Molybdenum, Nickel, Chromium, Vanadium, Tungsten, Cobalt, Silicon,Copper and Lead. | 1 | |
| | High speed steels:- Mo and W types, effect of different alloying elements in HSS | 1 | |
| | Cast irons: Classifications; grey, white, malleable and spheroidal graphite cast iron etc, composition, Microstructure, properties and applications. | 1 | |
| | Principal Non ferrous Alloys: - Aluminum, Copper, Magnesium, Nickel, study of composition, properties, applications, reference shall be made to the phase diagrams whenever necessary. | 1 | |
| **SECOND INTERNAL EXAMINATION** | | | |
| **V** | Fatigue: - Stress cycles – Primary and secondary stress raisers - Characteristics of fatigue failure, fatigue tests, S-N curve. | 1 | 20% |
| | Factors affecting fatigue strength: stress concentration, size effect, surface roughness, change in surface properties, surface residual stress. | 1 | |

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| | Ways to improve fatigue life – effect of temperature on fatigue, thermal fatigue and its applications in metal cutting | 1 | |
| | Fracture: – Brittle and ductile fracture – Griffith theory of brittle fracture – Stress concentration, stress raiser – Effect of plastic deformation on crack propagation. | 1 | |
| | Transgranular, intergranular fracture - Effect of impact loading on ductile material and its application in forging, applications - Mechanism of fatigue failure. | 1 | |
| | Structural features of fatigue: - crack initiation, growth, propagation - Fracture toughness (definition only) – Ductile to brittle transition temperature (DBTT) in steels and structural changes during DBTT, applications. | 1 | |
| **VI** | Creep: - Creep curves – creep tests - Structural change: deformation by slip, sub-grain formation, grain boundary sliding | 1 | 20% |
| | Mechanism of creep deformation - threshold for creep,prevention against creep - Super plasticity: need and applications | 1 | |
| | Composites:- Need of development of composites - geometrical and spatial Characteristics of particles – classification - fiber phase: - characteristics, classifications -composites:- Need of development of composites - | 2 | |
| | Modern engineering materials: - only fundamentals, need, properties and applications of, intermetallics, maraging steel, super alloys, Titanium – introduction to nuclear materials, smart materials and bio materials. | 2 | |
| | Ceramics:-coordination number and radius ratios- AX, AmXp, AmBmXp type structures – applications. | 1 | |
| **END SEMESTER EXAMINATION** | | | |

## QUESTION PAPER PATTERN

Maximum Marks : 100 Exam Duration: 3 Hrs

**PART A**
4 Questions uniformly covering modules 1 and 2. Each question carries 10 marks. Students will have to answer any three questions out of four. (3X10=30 marks)

**PART B**
4 Questions uniformly covering modules 3 and 4. Each question carries 10 marks. Students will have to answer any three questions out of four. (3X10=30 marks)

**PART C**
6 Questions uniformly covering modules 5 and 6. Each question carries 10 marks. Students will have to answer any four questions out of six. (4X10=40 marks)

**Note:** In all parts, each question can have a maximum of 4 sub questions, if needed.