NATIONAL INSTITUTE OF TECHNOLOGY WARANGAL

Minor in

MATERIALS ENGINEERING

SCHEME OF INSTRUCTION AND SYLLABI

(for B.Tech. students other Metallurgical and Materials Engineering)

(Effective from 2021-22)

DEPARTMENT OF

METALLURGICAL AND MATERIALS ENGINEERING

Scheme of Instruction

Minor: Materials Engineering

MINOR: Materials Engineering (3 credits x 6 courses = 18 credits)

S. No	Course Code	Course Name	Year/Sem
1	MMM01	Structure and Properties of Materials	2/1
2	MMM02	Engineering Materials	2/2
3	MMM03	Advanced Materials Testing	3/1
4	MMM04	Characterization Techniques	3/2
5	MMM05	Materials Degradation	4/1
6	MMM06	Advanced Materials	4/2

Course Code: MMM01	STRUCTURE AND PROPERTIES OF MATERIALS	Credits 3-0-0: 3

Pre-Requisites: None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Classify materials based on their structure
CO2	Correlate the structure with properties of materials
CO3	Analyse the binary phase diagrams
CO4	Appraise the importance of basic heat treatment processes

Syllabus:

Introduction: Historical perspective on materials, Classification of materials, Modern materials' needs, Materials tetrahedron, Bonding in solids - metallic bond, ionic bond, covalent bond.

Structure of solids: Crystal systems, Unit cells and space lattices, Coordination number, Metallic crystal structures, Atomic packing fraction for cubic and hexagonal close packed structures, Miller indices of planes and directions, Amorphous and polycrystalline materials. Ceramic crystal structures, Structure of polymers, Crystal imperfections – point defects, line defects, surface defects and volume defects.

Properties of materials: Physical properties, Thermal Properties, Electrical Properties, Magnetic Properties, Optical Properties, Mechanical properties, Structure-property correlations.

Constitution of alloys: Necessity of alloying, Substitutional and Interstitial solid solutions, Hume Rothery Rules, Intermediate phases.

Binary phase diagrams: Basic definitions, Gibbs phase rule, Construction of isomorphous phase diagram from cooling curves, Tie-line rule, Lever rule, Equilibrium heating and cooling of an isomorphous alloy, Eutectic, Eutectoid, Peritectic, Peritectoid, Monotectic and Syntectic reactions. Study of important binary systems of Fe-Fe_3C, Cu-Zn, Cu-Sn, Al-Cu and Al-Si, Introduction to strengthening mechanisms.

Basic heat treatment processes: Annealing, Normalising, Hardening and Tempering, Carburising, Nitriding, Influence of these processes on properties.

Text books:

1. W.D. Callister, D.G. Rethwisch, Materials science and Engineering: An Introduction, 8th ed., Wiley, 2010.
2. S.H. Avener, Introduction to Physical Metallurgy, 2nd ed., Tata McGraw-Hill Education, 2011.
3. V. Raghavan, Materials Science & Engineering: A first course, 5th ed., PHI Learning, 2004.
4. R E. Hill and Abbaschain, Physical Metallurgy Principles, PWS Publishing Company, 4nd ed., 2009.

Reference books:

1. D S Clark and W. R. Varney, Physical Metallurgy for Engineers, CBS Publications, 1st ed., New Delhi, 1979.
2. R. E. Smallman A.H.W. Ngan, Modern Physical Metallurgy, 6th ed., Butterworth-Heinemann Publications, 1999.

Online resources:

1. https://nptel.ac.in/courses/112/108/112108150/
2. https://nptel.ac.in/courses/113/106/113106032/
3. https://nptel.ac.in/courses/113/102/113102080/

Course Code: MMM02	ENGINEERING MATERIALS	Credits 3-0-0: 3

Pre-Requisites: None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Classify materials based on structure and properties
CO2	Describe structure, properties and applications of ferrous and non-ferrous alloys
CO3	Differentiate metals/polymers/ceramics and their composites
CO4	Suggest materials for a given engineering application

Syllabus:

Introduction: Historical perspective of engineering materials, importance of materials, materials for daily life, need for new materials development. **Metallic materials**: ferrous alloys- carbon steels, low & high alloy steels, stainless steels, special steels: HSLA, duplex, marageing, HNS, light-weight steels, Fe-Si alloys, cast irons, non-ferrous alloys: aluminium, magnesium, titanium and nickel alloys. **Ceramics**: typical structure of ceramics, glasses, silicate ceramics, carbon fibres, glasses. **Polymers**: polymerisation, thermosetting and thermoplastics, polymeric materials for special applications: high temperature, absorbing high energy impacts, limitations. **Composites**: classification based on matrix and dispersed phase, reinforced concrete, carbo-carbon composites, applications and limitations.

Text books:

1. Structure and Properties of Engineering Alloys, Smith, McGraw-Hill Book Co., 2nd ed., 1993.
2. Engineering materials, A. K. Bhargava, PHI Learning Private Limited, 2nd ed., 2013.
3. Engineering Materials: Properties and Selection, Kennath Budinski, Michel K Budinski, Pearson Education India, 9th ed., 2009.
4. Materials – Introduction & Applications, Witold Brostow, H E Hagg Lobland, Wiley & Sons, 2017.
5. Science and Engineering of Materials, Donald R. Askeland, Pradeep P. Phule, Thomson Learning, 5th ed., 2007.
6. An Introduction to Materials Engineering and Science: for Chemical and Materials Engineers, Brian S. Mitchell, John Wiley & Sons, Inc., 2004.
7. Materials Science and Engineering – A First Course, V. Raghavan, Prentice Hall of India Private Limited, 4th ed., 1999.

Course Code: MMM03	ADVANCED MATERIALS TESTING	Credits 3-0-0: 3

Pre-Requisites: None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Discuss the destructive testing methods to measure the mechanical properties
CO2	Explain creep and stress rupture test and their implications
CO3	Explain the working principles of non-destructive testing (NDT) methods
CO4	Identify suitable NDT methods for defect detection

Syllabus:

Destructive Tests: Hardness test, Tensile test, Compression test, Impact test, Microhardness and indentation fracture toughness test, Fracture toughness test, Creep test, Fatigue test. **Non-Destructive Tests:** Introduction to NDT, Classification of NDT processes, Working principle, advantages, disadvantages of Liquid penetrant testing, Eddy Current Testing, Magnetic Particle Testing, Radiographic Testing, Ultrasonic Testing and Acoustic Emission Testing. Precautions against radiation hazards.

Text Books:

1. Mechanical Metallurgy, G. E. Dieter, McGraw-Hill, 2002.
2. R. W. Hertzberg: Deformation and Fracture Mechanics of Engineering Materials, 4th Edition, John Wiley & Sons Inc., 2012.
3. Practical Non-Destructive Testing, Baldev Raj, T.Jayakumar, M.Thavasimuthu, Narosa Publishing House, 2014.
4. Non-Destructive Testing Techniques, Ravi Prakash, New Age International Publishers, 2010, 1st revised edition.

Reference Books:

1. T. L. Anderson: Fracture Mechanics- Fundamentals and Applications, 3rd Edition, CRC Press, 2011.
2. ASM Metals Handbook, Non-Destructive Evaluation and Quality Control, American Society of Metals, Metals Park, Ohio, USA, Volume-17.
3. Charles, J. Hellier, Handbook of Nondestructive evaluation, Charles, J. Hellier, McGraw Hill, New York, 2001.

Online Resources:

1. www.ndt.edu
2. www.nde-ed.org

Course Code: MMM04	CHARACTERIZATION TECHNIQUES	Credits 3-0-0:3

Pre-Requisites: None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Describe the principles of optical and electron microscopy.
CO2	Analyse the X-ray diffraction data.
CO3	Choose suitable characterization techniques for microstructural analysis of materials.
CO4	Select suitable characterization techniques for compositional analysis of materials.
CO5	Apply thermal analysis techniques for materials characterization.

Syllabus:

Microscopy: Working principle of microscope, optical microscope, concepts of magnification, resolution, numerical aperture, depth of field, principles of image formation, advantages, limitations and applications. Electron microscopy, SEM and TEM, electron source, electron-specimen interaction, mode of imaging, image contrast, SAD. Comparison of OM, SEM and TEM. Advantages, limitations and applications. **X-Ray diffraction**, Properties of X-rays, X-Ray diffraction methods, applications of XRD. **Composition analysis techniques:** EDS, WDX, XRF, XPS and AES, and EPMA. **Thermal analysis techniques** TGA, DSC, DTA and TMA.

Text Books:

1. Materials Characterization Techniques, S Zhang, L. Li and Ashok Kumar, CRC Press, 2008.
2. David B. Williams, C. Barry Carter, Transmission Electron Microscopy, Textbook for Materials Science, Springer, 2nd Edition, 2009.
3. An Introduction to Material Characterization, Khangaonkar P R, Penram Intl. Publishing (India) Pvt. Ltd, Mumbai, 2010.
4. Elements of X-Ray Diffraction, B.D.Cullity and S.R.Stock, 3rd Edition, Prentice Hall, NJ, 2001.

Reference Books:

1. ASM Handbook, Vol.10, Materials Characterization, ASM International, USA, 1998.
2. Scanning electron microscope (SEM) instrumentation: Scanning Electron Microscopy and X-Ray Microanalysis. Springer, Goldstein JI, Newbury DE, Michael JR, Ritchie NW, Scott JH, Joy DC New York, NY, 4th Edition, 2018.
3. Practical of Electron Microscope in material science: Electron Diffraction in the Electron Microscope- J. W. Edington, (Philips Technical Library) Macmillan Education UK (1975).
4. Practical of Electron Microscope in material science: J Interpretation of Transmission Electron Micrographs - J. W. Edington, (Philips Technical Library) Macmillan Education UK (1975).

Online Resources:

1. https://onlinecourses.nptel.ac.in/noc21_mm07/preview
2. https://youtu.be/KfQ4VNpWN4M
3. https://www.youtube.com/watch?v=UuHofNW40Yw
4. https://www.youtube.com/watch?v=Mr9-1Sz_CK0
5. https://www.youtube.com/watch?v=ArPXfPjOJQc
6. https://www.youtube.com/watch?v=07iZ7-IEyYE
7. https://www.youtube.com/watch?v=yguvwX_ia_A&list=PLqj8pra18A5NUV8lYJKBfwMBGt5k9Fe5c&index=2
8. https://www.youtube.com/watch?v=EItYvqOQe5w&list=PLqj8pra18A5NUV8lYJKBfwMBGt5k9Fe5c&index=1

9. https://www.youtube.com/watch?v=GIqam7DEPY4&list=PLqj8pra18A5NUV8lYJKBfwMBGt5k9Fe5c&index=7
10. https://www.youtube.com/watch?v=Kilrxi2wIoA&t=7s
11. https://www.youtube.com/watch?v=9J83u8fxCRk

Course Code: MMM05	MATERIALS DEGRADATION	Credits 3-0-0: 3

Pre-Requisites: None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Discuss the thermodynamic and kinetic principles governing the material degradation in aqueous environment
CO2	Explain corrosion mechanisms of materials in industry
CO3	Predict the corrosion behaviour from corrosion data of material
CO4	Select suitable materials/methods for corrosion prevention using electrochemical and metallurgical principles

Syllabus:

Environmental degradation of a material: Definition and significance, overview of common material failures due to environmental degradation in industry, corrosion - basic definition and its cost.

Thermodynamics of metallic corrosion: EMF series and Nernst's law, EMF vs corrosion potential, Pourbaix diagram – construction, applications and examples, Effect of environmental variables on corrosion, passivity in metals and alloys

Kinetic of corrosion, corrosion rate expressions, polarisation: Types, mixed potential theory, Evans diagram – construction and interpretation

Forms of corrosion: Uniform, dealloying, intergranular, galvanic, crevice, pitting, environmentally induced cracking – types, erosion corrosion - cavitation, high temperature corrosion- oxidation- Ellingham diagrams, hot corrosion, microbially induced corrosion

Corrosion testing procedures: Weight loss, spectroscopy and electrochemical methods, polarisation methods – linear, cyclic and Tafel methods, electrochemical impedance spectroscopy, potentiostatic and galvanostatic techniques to study passivity

Corrosion control, monitoring and prevention: change of environment, material design and optimisation - effect of metallurgical variables on corrosion, sorting of metallic materials based on their corrosion behaviour in various environments such as fresh water, marine and soil, anodic and cathodic protection, coatings, corrosion of non-metallic materials-composites, polymers and ceramics.

Text Books:

1. Principles and Prevention of Corrosion, Denny A. Jones, Prentice Hall, 2nd Edition, 1996.
2. Corrosion Engineering, Mars G. Fontana, McGraw-Hill Book Company, 3rd Edition, 1986.

Reference Books:

1. Fundamentals of Metallic Corrosion: Atmospheric and Media Corrosion of Metals, Philip A. Schweitzer, CRC Press, 2nd Edition, 2006.
2. An Introduction to Corrosion and Corrosion Engineering, H.H. Uhlig, R. Winston Revie, John Wiley & Sons, 4th Edition, 2008.

Online Resources:

1. https://nptel.ac.in/courses/113/108/113108051/#
2. https://nptel.ac.in/courses/113/104/113104082/#

Course Code: MMM06	ADVANCED MATERIALS	Credits 3-0-0: 3

Pre-Requisites: None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Describe synthesis, properties, applications of nanomaterials
CO2	Suggest advanced composite materials for innovative applications
CO3	Discuss unique aspects of bulk metallic glasses and high entropy alloys
CO4	Suggest appropriate biomaterials for desired biomedical applications

Syllabus:

Introduction: Introduction to advanced materials, classification.

Advanced Nanomaterials: Introduction, Classification of nanomaterials, Physical, chemical, mechanical properties of nanomaterials; applications. Preparation of nanomaterials by solid, liquid and vapour routes; Carbon nanotubes (CNTs), preparation, properties and applications, Graphene and other emerging 2-D nanomaterials

Advanced Composites: General characteristics and classification of composites, Advanced metal-matrix composites (AMMCs), advanced ceramic matrix composites (ACMCs), advanced polymer matrix composites (APMCs), hybrid composites; Types of reinforcements, interface bonding, toughening mechanism, Unique properties, Applications in structural and aerospace sectors, Nanocomposites

Bulk metallic glasses (BMGs) and High entropy alloys (HEAs): Introduction to metallic glasses, Glass formation, essential properties and applications of BMGs, synthesis through solid and liquid routes. HEAs: Concept of thermodynamic stability, essential properties, applications and synthesis of HEAs

Advanced Biomaterials: Overview of biomaterials, Biocompatibility; Advanced biometallics, bioceramics, biopolymers, applications; cardiovascular implants, orthopedic implants, ophthalmology biomaterials, dental materials, Nanobiomaterials for medical imaging.

Text Books:

1. Introduction to Nanotechnology, Charles P. Poole Jr., Frank J. Owens, Wiley India, New Delhi, 2010.
2. Composite Materials, Krishan K. Chawla, Springer, 3rd Ed., 2015.
3. Bulk Metallic Glasses, C. Suryanarayana and A. Inoue, CRC Press, 2017.
4. Biomaterials Science and Tissue Engineering: Principles and Methods, Bikramjit Basu, Cambridge Press, 2017.

Reference Books:

1. Structural Nanocrystalline Materials: Fundamentals and Applications, Carl C. Koch, Ilya A. Ovid'ko, Sudipta Seal, and Stan Veprek, Cambridge Press, 2007.
2. Textbook of Nanoscience and Nanotechnology, B. S. Murty et al., Universities Press, 2013.

Online Resources:

1. https://nptel.ac.in/courses/113/105/113105081/
2. https://nptel.ac.in/courses/113/105/113105057/