Advanced Materials Science

1. **Course number and name:** 020SMAES4 Advanced Materials Science

2. **Credits and contact hours:** 4 ECTS credits, 2x1:15 contact hours per week

3. **Name(s) of instructor(s) or course coordinator(s):** Ali Harkous

4. **Instructional Materials:** PowerPoint slides; Videos.

   Textbooks/References:
   - Materials Science and Engineering: An Introduction, 9th edition, William D. Callister and David G. Rethwisch, Wiley, 2014.
   - Fundamentals of Modern Manufacturing, 7th edition, M.P. Groover, Wiley, 2020.
   - Manufacturing Engineering and Technology, 8th edition in SI units, S. Kalpakjian, Pearson Education, 2020.
   - Introduction to Materials Science for Engineers, 8th edition, J.F. Shackelford, Pearson, 2015.
   - Introduction to Polymers, 3rd edition, R.J. Young and P.A. Lovell, CRC Press, Taylor & Francis Group, 2011.
   - Polymer Science and Technology, 3rd edition, J.R. Fried, Pearson Education, 2014.

5. **Specific course information**
   a. **Catalog description:**
      This course deals with metals and polymers. The ferrous and non-ferrous alloys section covers the following aspects: mechanical behavior of metals, phase diagrams; fabrication of metals, heat treatment, surface properties of metals; plastic deformation, elements of fracture mechanics; and process-structure-property relationships. The polymers' part covers their properties, polymerization and synthesis, characterization techniques, physical properties of polymers, viscoelasticity, mechanical properties and applications.

   b. **Prerequisite:** Introduction to Materials Science (020ISMNI2).

   c. **Selected Elective** for ME students.

6. **Educational objectives for the course**
   a. **Specific outcomes of instruction:**
      - Analyze the mechanical behavior of metals and identify the different types of deformation.
      - Interpret a phase diagram and describe the development of the microstructure based on the type and the composition of a metal alloy.
      - Distinguish ferrous and non-ferrous metals, and describe their extraction process, structure, and properties.

- Consider the importance of heat treatment and surface properties of a metal and choose the best treatment method to enhance a required property.
- Recognize the mechanisms of plastic deformation and failure of metals.
- Illustrate the different methods of polymer synthesis and the structure of thermoplastics, thermosets, and elastomers.
- Define the main physical and mechanical properties of polymers.
- Consider the importance of viscoelastic behavior of polymers and rubbers in the final performance of a product.
- Associate the properties of polymers with the corresponding characterization technique.

b. PI addressed by the course:

PI	1.3	2.1	2.2	2.3
Covered	x	x	x	x
Assessed				

7. Brief list of topics to be covered

- **Chapter 1: Introduction and Review of the Mechanical Properties of Metals:** Mechanical Behavior – Concepts of stress and strain – Properties related to elastic deformation – Properties related to plastic deformation – Property variability and design/safety factors. (2 Lectures).
- **Chapter 2: Alloys and Phase Diagrams of Metals:** Definitions and Basic Concepts – Review: One-component Phase Diagrams of Water – Binary Isomorphous Systems – Interpretation of Phase Diagrams – Development of Microstructure in Isomorphous Alloys – Binary Eutectic Systems – Development of Microstructure in Eutectic Alloys – The Iron-Carbon System. (4 Lectures).
- **Chapter 3: Extraction, Preparation, and Processing of Metal Alloys:** Ferrous Metals and Alloys: Production, General Properties, and Applications – Nonferrous Metals and Alloys: Production, General Properties, and Applications – Fabrication of Metals. (2 Lectures).
- **Chapter 4: Heat Treatment of Metal Alloys:** Heat Treatment of Ferrous Alloys – Hardenability of Ferrous Alloys – Heat Treatment of Nonferrous Alloys and Stainless Steels – Case Hardening – Annealing – Heat Treatment Methods and Facilities. (2 Lectures).
- **Chapter 5: Properties and Treatment of Metallic Surface:** Surface Roughness and Measurement – Friction – Wear – Lubrication – Metalworking Fluids and Their Selection – Surface Treatments – Coatings – Cleaning. (2 Lectures).
- **Chapter 6: Dislocations, Plastic Deformation, and Failure Mechanics:** Dislocations and Plastic Deformation: Basic Concepts, Characteristics of Dislocations, Slip Systems, Plastic Deformation of Polycrystalline Materials, Deformation by Twinning – Fracture – Fatigue – Creep. (5 Lectures).

- **Chapter 7: Structure and Synthesis of Polymers:** Structure – Thermoplastics – Thermosetting Polymers – Elastomers – Principles of Polymerization – Biodegradable Plastics – Defects in Polymers – Diffusion in Polymeric Materials. (2 Lectures).

- **Chapter 8: Physical Properties and Characterization of Polymers:** General Physical properties (Density; Melting Point; Specific Heat; Thermal Conductivity; Thermal Expansion; Electrical, Magnetic, and Optical Properties; Corrosion Resistance) – Crystallization – Melting – Glass transition Phenomena – Characterization: Spectroscopic Techniques – X-ray Diffraction – Transmission Electron Microscopy and Diffraction – Scanning Electron Microscopy – Optical Techniques – Thermal Analysis. (2 Lectures).

- **Chapter 9: Mechanical Properties, Processing, and Applications of Polymers:** Mechanical Behavior of Polymers: Stress-Strain Behavior, Mechanical properties, Macroscopic Deformation, Viscoelastic Behavior of Polymers, Fracture of Polymers – Mechanisms of Deformation and Strengthening of Polymers – Processing of Polymers: Forming Techniques for Plastics, Fabrication of Elastomers, Fabrication of Fibers and Films – General Applications of Thermoplastics, Thermosets and Elastomers. (3 Lectures).