DIM-SAP-337 Introduction to Materials and their Applications

SEMESTER: Spring

CREDITS: 6 ECTS (4 hours. per week).

LANGUAGE: English.

DEGREES: SAPIENS program

Course overview:

The course introduces the student to the following topics: structure of materials and defects in solids; diffusion processes in solid state; chemical composition and phase transformations; mechanical properties of metals; properties and applications of metal alloys, ceramics, polymers, composites and biomaterials: and mechanisms of degradation of materials. Methodologies for material selection in engineering applications is also emphasized. In addition to lectures, students will carry out lab activities and practical sessions to solve real problems, which will be fundamental and mandatory to a better understanding of the concepts covered in the lectures.

Prerequisites:

A basic knowledge of introductory engineering design and calculus is needed and, in particular, basic knowledge of chemistry, chemical bonding and crystalline systems.

Course contents:

Theory:

UNIT 1: INTRODUCTION

1. Concept of process-structure-property relationships.
2. Materials classifications: metals, ceramics, polymers, composites, advanced materials.
3. Materials selection.

UNIT 2: OVERVIEW OF MATERIALS

1. Atomic structure and the periodic table.
2. Atomic bonding in solids.
3. Crystalline structures: unit cells, common structures, crystal systems, density calculations.
4. Crystallographic directions and planes.
5. Carbon polymorphic forms: diamond, graphite, fullerenes, carbon nanotubes and graphene.
6. Noncrystalline solids.

UNIT 3: DEFECTS IN SOLIDS

1. Point defects in metals and ceramics.
2. Impurities in solids.
3. Linear defects: Dislocations.
4. Interfacial defects: External surface, grain boundaries and phase boundaries.
5. Volume defects.
6. Grain size determination.

UNIT 4: MECHANICAL PROPERTIES

1. Material testing.
2. Stress-strain curve.
3. Plastic and elastic deformation.
4. Mechanical parameters.
5. Fracture: ductility, brittleness.
6. Hardness.

UNIT 5: DEFORMATION AND STRENGTHENING MECHANISMS

1. Dislocations, slip directions and plastic deformation.
2. Mechanisms of strengthening in metals.
3. Recovery, recrystallization and grain growth.

UNIT 6: POLYMERS

1. Structure of the polymer molecules and common polymers.
2. Molecular weight and degree of polymerization.
3. Thermoplastics and thermosets.
4. Crystallinity.
5. Mechanical properties of polymers.
6. Influence of the temperature.
7. Viscoelasticity.

UNIT 7: DIFFUSION

1. Types and mechanisms of diffusion.
2. Steady-state and nonsteady-state diffusion.
3. Diffusion factors.
4. Diffusion applications.

UNIT 8: PHASE DIAGRAMS AND PHASE TRANSFORMATIONS

1. Fundamental concepts
2. Binary phase diagrams: Isomorphous alloys (Cu-Ni), eutectic systems (Pb-Sn)
3. The iron-carbon system.
4. Phase transformations: kinetics, TTT and CCT diagrams, metastable vs stable transformations.
5. Precipitation hardening of aluminium alloys.

UNIT 9: COMPOSITES

1. Introduction.
2. Particle-reinforced composites.
3. Fiber-reinforced composites.

4. Structural composites.

UNIT 10: DEGRADATION OF MATERIALS

5. Degradation of metals: electrochemical and chemical corrosion.
6. Degradation of polymers: swelling and dissolution, bond rupture, weathering.

UNIT 11: FAILURE

1. Principles of fracture mechanics.
2. Fatigue: S-N curve.
3. Creep.

Laboratory:

In addition to lectures, students will carry out 6 lab sessions, related to the theoretical concepts seen in class. Each session will be 2-hours-long. The students will be divided into groups of 3-4 people, and each group must deliver a report about the concepts reviewed during each session, at the end of each activity. These activities will lead to a better understanding of the theoretical concepts.

Lab 1: Grain size: Gran size determination and relationship with hardness (HV).

Lab 2: Mechanical properties: Stress-strain curve obtention of steel and Al. HRB and HRC.

Lab 3: Materials selection: With CES EduPack (Granta).

Lab 4: Polymers: Synthesis of and polyurethane foam. Characterization of polymers.

Lab 5: Phase diagrams and corrosion: Cooling curves of different Sn-Pb alloys. Types of corrosion (uniform, galvanic).

Lab 6: Composite materials: Fabrication of a CFRP laminate and mechanical characterization.

Textbook: Callister, William D., Jr., and Rethwisch, David G., Fundamentals of Materials Science and Engineering: An Integrated Approach, 5 th Ed., John Wiley and Sons, 2015.

Methodology

1. **Expository lessons:**

The teacher will explain the concepts through presentations and the resolution of practical exercises. The PDF versions of the theoretical presentations, corresponding to every unit, as well as the list of exercises will be accessible for students through the Moodlerooms platform.

2. **Lab sessions:**

Students will carry out 6 lab sessions, related to the theoretical concepts seen in class. Each session will be 2-hours-long. The students will be divided into groups of 3-4 people. Once the activity is concluded, each group must deliver a report about the main concepts reviewed during each session, according to their protocols.

3. **Tutorials:**

In order to clarify any aspect of the subject, students will be able to request individual tutorials (with no more than 3 people at the same time), both to the lab and theory teachers, upon previous request to them by mail.

4. **Visits:**

In addition to lectures and lab activities, but only if the university's agenda, the classes planning, and the availability of the centers allow it, the teachers will organize 1 or 2 visits to Spanish centers specialized in materials science.

Grading

Ordinary examination:

The score for the ordinary final mark will be obtained by:

50% written examination,

30% follow-up examinations,

20% lab sessions (≥ 5.0).

* The lack of attendance to some of the activities is a 0 in that session.

* A delay in the delivery of reports means a minimum penalty of 2 points.

Extraordinary examination:

The score for the extraordinary final mark will be obtained by:

80% written examination (≥ 5.0),

20% lab sessions.

Schedule:

Unit	Subject	Hours
U1	Introduction	1
U2	Overview of materials	4
U3	Defects in solids	3
U4	Mechanical properties	6
U5	Deformation and strengthening mechanisms	3
U6	Polymers	4
U7	Diffusion	3
U8	Phase diagrams and phase transformation	8
U9	Composites	3
U10	Degradation of materials	4
U11	Failure	3
		42

LAB	Subject	Hours
Lab 1	Grain size.	2
Lab 2	Mechanical properties	2
Lab 3	Materials selection (SW CES EduPack)	2
Lab 4	Polymers	2
Lab 5	Phase diagrams and corrosion	2
Lab 6	Composite materials	2
		12

Exams (midterm I, midterm II, final)	6

TOTAL hours	60