NATIONAL UNIVERSITY OF ENGINEERING
COLLEGE OF GEOLOGICAL, MINING AND METALLURGICAL ENGINEERING

METALLURGICAL ENGINEERING PROGRAM

ME429 – PHYSICAL METALLURGY

I. GENERAL INFORMATION

CODE	:	ME429 Physical Metallurgy
SEMESTER	:	8
CREDITS	:	4
HOURS PER WEEK	:	6 (Theory–Practice–Laboratory)
PREREQUISITES	:	ME322 Solidification
CONDITION	:	Compulsory
DEPARTMENT	:	Metallurgical Engineering

II. COURSE DESCRIPTION

This course prepares students in the understanding of the physics of metals, referred to their modular and crystalline atomic structure, under the concepts of quantum theory, and applied to transformation metallurgy. Students also understand and analyze the thermodynamic processes of solid-liquid systems in metals, as well as the kinetics of vacancies and dislocations. Also, students solve problems on the relative movement of electron-nucleus systems, analyze phase diagrams of a system of alloys, as well as the behavior of curves of free energy- chemical composition. On the other hand, the course also motivates students to deep in the study and research of transformation metallurgy.

III. COURSE OUTCOMES

At the end of the course, students:

1. Design materials and alloys using mathematical modeling of atomic orbitals, molecular links, molecular orbitals and crystalline networks.
2. Construct the thermodynamic diagram of phases of any alloy system.
3. Interpret the changes of phase in any alloys system, using the proper diagram of phases.
4. Explain the formation of substitutional and interstitial solid solutions, and intermetallic compounds depending on the solubility of alloying atoms in the network of solvent atoms.
5. Understand the behavior of any alloy when it is exposed to the action of thermal energy.
6. Elaborate alloys with the required mechanical, thermal, chemical, electrical, and magnetic properties for a specific industrial application.

IV. LEARNING UNITS

1. INTRODUCTION

Materials testing / Transformation metallurgy fundamentals / Materials design fundamentals / Classic genesis of materials internal structure / Heisenberg’s Uncertainly Principle.

2. QUANTUM MODEL OF ATOMIC STRUCTURE – QUANTUM MODEL OF MOLECULAR STRUCTURE

Quantum theory principles / Quantum numbers deduction / Relative motion of electrons respect to atom nucleus / Energy bands around atom nucleus / Quantum modeling of energy bands. Atomic orbital and suborbital / The atom from quantum concepts and the function of quantum numbers / Quantum models of molecular structures / Molecular links / Material properties according to the molecular cohesion of used chemical elements.

3. QUANTUM MODEL OF CRYSTALLINE STRUCTURES – METALLOGRAPHIC AND CRYSTALLOGRAPHIC CHARACTERISTICS

Spatial networks, elemental reticle / Fundamental networks / Crystalline systems / Monocrystalline and polycrystalline systems / Crystalline network defects /Metallography by optical microscopy / Metallography by electronic microscopy / Diffraction microscopy / Free electron theory.

4. **PHASE TRASFORMATION SOLID – LIQUID – GAS, ALLOYS, SOLUBILITY OF SOLID PHASE, METALLIC SYSTEMS THERMODYNAMICS**
Frequency and amplitude of atomic vibrations produced by thermal energy / Phase transformation, solid-liquid-gas. / Nucleation and growing in solidification / Solidification curves and phase diagrams – Alloys and alloy systems / Solubility in solid phase / Thermodynamics of metallic systems.

5. **THERMODYNAMICS OF ISOMORPHIC ALLOY SYSTEMS; EUTECTIC-EUTECTOID; PERITECTIC-PERITECTOID**
Thermodynamic analysis of isomorphic alloy systems / Thermodynamic analysis of eutectic-eutectoid alloy systems. / Thermodynamic analysis of peritectic-peritectoid alloy systems / Analysis of multicomponent alloy systems / Phase diagram of alloys from thermodynamic analysis.

6. **SOLID PHASE KINETICS - ATOMIC DIFFUSION**
Atomic diffusion due to concentration gradient, Fick's laws / Atomic diffusion due to chemical potential gradient, thermodynamic laws / Kirkendal phenomenon analysis. Slip and rise of dislocations / Interaction and dislocation rings / Dislocations generation, Frank Read's sources and nucleation.

V. PRACTICE WORK

Session 1: Crystalline structures of minerals and metals.
Session 2: Qualitative and quantitative analysis of crystalline samples using PowderCell.
Session 3: Use of software Thermocalc for binary equilibrium diagrams.
Session 4: Use of software Thermocalc for ternary equilibrium diagrams.
Session 5: Microstructure analysis. Heating treatments.
Session 6: Use of software Image J for image analysis.
Session 7: Ferrous alloys metallography by optical microscopy.
Session 8: Non-ferrous alloys metallography by optical microscopy.

VI. METHODOLOGY

The course takes place in theory, practice and laboratory sessions. In theory, faculty presents and analyze concepts and methods. In practice sessions diverse problems related to alloys design, quantum modeling, phase diagrams and thermodynamics of alloy systems are solved and analyzed. In laboratory sessions, students perform experimental tests and verify expected outcomes and results. After each laboratory experience, students submit a report describing procedures and summarizing results and conclusions. Student's active participation is promoted.

VII. GRADING FORMULA

The Final Grade PF is calculated as follow:

PF = (EP + EF + PL) / 3

EP: Mid-term Exam EF: Final Exam
PP: Average of Practice and Laboratory Works.

VIII. BIBLIOGRAPHY

1. PHILLIPS, L.F.
   Quantic Basic Chemistry
2. LAUGHLIN David
   Physical Metallurgy
3. BARROW.
   Physical Chemistry