MASTER OF SCIENCE
IN ENGINEERING

Module Description

The Physics of Materials and Engineering Devices

General Information

Number of ECTS Credits

3

Abbreviation

FTP_Physics

Version

04.11.2011

Responsible of module

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Language

	Lausanne	Bern	Zürich
Instruction	☒ E ☒ F	☐ D ☐ E ☐ F	☒ D ☒ E
Documentation	☒ E ☐ F	☐ D ☐ E ☐ F	☐ D ☒ E
Examination	☒ E ☒ F	☐ D ☐ E ☐ F	☒ D ☒ E

Module category

☒ Fundamental theoretical principles
☐ Technical/scientific specialization module
☐ Context module

Lessons

☒ 2 lecture periods and 1 tutorial period per week
☐ 2 lecture periods per week

Brief course description of module objectives and content

The students understand and are able to explain the basic principles of important engineering devices in relation to material properties and by applying microscopic concepts. These concepts include electrons and holes in solids, energy band structures of metals and semiconductors, polarization mechanisms in piezoelectric materials and in dielectrics, elementary dipole moments in magnetic materials and pairing of electrons in superconductors (Cooper pairs). Actual applications such as thermocouples, photovoltaic cells (solar cells), light emitting diodes (LED), piezoelectric actuators, magnetic sensors and data storage devices can be discussed by means of these concepts. This module will allow the students to understand modern concepts of innovative technologies and use them in the future.

Aims, content, methods

Learning objectives and acquired competencies

The students
- understand the thermal and electric conduction in solids using the kinetic description of particles
- can relate thermal conduction to electric conduction via microscopic models
- are able to describe the principles of thermocouples and diodes by means of energy bands, Fermi energy and contact potential
- can explain the physical origin and technical realization of nanometer vertical resolution of scanning probe microscopes (atomic force microscope, scanning tunnelling microscope)
- know the classification of magnetic materials and name examples of their technological applications
- understand the difference between the Meissner effect of a superconductor and a perfect diamagnetic material
- are capable to solve quantitative problems to all topics of this module

Contents of module with emphasis on teaching content

Elementary concepts of materials are studied with emphasis on applications. The module is divided into four sections:

1. Concept of thermal and electrical conduction in solids
   - Thermal fluctuation, noise and thermal activation (Arrhenius plots)
   - Thermal conduction (Wiedemann-Franz law)
   - Electrical conduction (Drude model), drift velocity and relaxation time
   - Temperature dependence of resistivity, ideal pure metals

2. Concept of energy bands in semiconductors, metals and insulators
   - Electrons and holes, effective electron mass
   - Doping: n-type, p-type
   - Ensemble of particles, Fermi-Dirac statistic
   - Contacts: ideal p-n junction (diode), pure metal contact and thermocouples
   - Devices: photovoltaic cell (solar cell), light emitting diode (LED), semiconductor laser
3. Piezoelectric and dielectric materials
   - Polarization mechanisms
   - Piezoelectricity, actuators and sensors, scanning tunneling and atomic force microscope (STM/AFM)
   - Dielectric constant and its frequency dependence
   - Refractive index and dispersion
   - Light absorption
4. Magnetic properties and superconductivity
   - Magnetization and magnetic permeability
   - Classification of magnetic materials: diamagnetic, paramagnetic, ferromagnetic, antiferromagnetic, ferrimagnetic
   - Magnetic domains and magnetic data storage
   - Superconductivity: zero resistance and critical current density, applications of large magnetic fields
   - Measuring magnetic fields: Hall effect, magnetic flux quantization and SQUID (Superconducting Quantum Interference Device)

Teaching and learning methods

- Instruction teaching: presentation and discussion of fundamental concepts
- Exercises: solving quantitative problems and analyzing the physical concepts of applied technological devices
- Autonomous learning using a given textbook

Prerequisites, previous knowledge, entrance competencies

Basics of classical physics and mathematics (bachelor level)

Literature

Principles of Electronic Materials and Devices, Safa O. Kasap, McGraw Hill

Assessment

Certification requirements for final examinations (conditions for attestation)

Defined by the professors, for example a certain number of problems solved

Written module examination

Duration of exam :	120 minutes
Permissible aids:	Defined by the professors, for example lecture notes and one textbook.