

**Module Description**

# The Physics of Materials and Engineering Devices

**General Information**
**Number of ECTS Credits**

3

**Abbreviation**

FTP\_Physics

**Version**

2.12.2016

**Responsible of module**

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**Language**

	Lausanne	Bern	Zürich
Instruction	<input type="checkbox"/> E <input checked="" type="checkbox"/> F	<input type="checkbox"/> D <input type="checkbox"/> E <input type="checkbox"/> F	<input type="checkbox"/> D <input checked="" type="checkbox"/> E
Documentation	<input checked="" type="checkbox"/> E <input type="checkbox"/> F	<input type="checkbox"/> D <input type="checkbox"/> E <input type="checkbox"/> F	<input type="checkbox"/> D <input checked="" type="checkbox"/> E
Examination	<input checked="" type="checkbox"/> E <input checked="" type="checkbox"/> F	<input type="checkbox"/> D <input type="checkbox"/> E <input type="checkbox"/> F	<input type="checkbox"/> D <input checked="" type="checkbox"/> E

**Module category**

- Fundamental theoretical principles
- Technical/scientific specialization module
- Context module

**Lessons**

- 2 lecture periods and 1 tutorial period 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**

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