MASTER OF SCIENCE
IN ENGINEERING

Module Description, available in: EN

Physics on micro and nano scale

General Information

Number of ECTS Credits

3

Module code

FTP_PhyMNS

Valid for academic year

2026-27

Last modification

2024-10-21

Coordinator of the module

Wolfgang Tress (ZHAW, trew@zhaw.ch)

Explanations regarding the language definitions for each location:

- Instruction is given in the language specified for each location and module execution.
- Documentation is available in the language(s) listed for each location and module execution. If the documentation is in multiple languages, the percentage distributed is indicated (100% = all documentation provided).
- The examination, including both questions and answers, is provided entirely (100%) in the language(s) specified for each location and module execution. The exams are on-site.

	Lausanne			Lugano	Zurich		
Instruction					**X** E 100%		
Documentation					**X** E 100%		
Examination					**X** E 100%		

Module Category

FTP Fundamental theoretical principles

Lessons

2 lecture periods and 1 tutorial period per week

Entry level competences

Prerequisites, previous knowledge

- Optics: Basics of wave optics;
- Physics: The students are able to solve simple differential equations, know linear algebra and can handle electromagnetic forces and fields.
- Mathematics: Basics for engineers (bachelor level)

Brief course description of module objectives and content

The module “Physics on micro and nano scale” focuses on physical effects and their applications in photonics, electrical engineering, medical engineering and mechanical engineering which become relevant, when technical systems get miniaturized. In the first step of miniaturization - from macro to micro – the principal physics remains unchanged, but the dominant physical effects change due to a changed surface to volume ratio. Surface related effects become dominant. With further miniaturization – from micro to nano - quantum phenomena become dominant and lead to completely new physical concepts. When the typical size of objects is between several nanometers and a few micrometres, we can observe a wealth of fascinating effects that today are the basis for applications from advanced sensing to medical applications, ultrasmall mechanical devices, nanophotonics etc.

A first topic of this module relates to surface effects. Microstructured surfaces and surface functionalization play an important role in mechanical systems in terms of nano-roughness and nanotribological properties. The functionalization can be designed to reduce e.g. wear, corrosion, ice-formation or bio-fouling, and finds application in biosensors. In nature, such microstructures lead e.g. to the Lotus effect or to different colour effects, and in medicine, micro and nanostructured surfaces help to significantly improve the acceptance of implants by the human organism.

A second topic deals with quantum effects that are related to spatial confinement in physical systems. The discretization of energy levels in atomic systems, for example, forms the basis for the understanding of light-matter interaction. Prohibited states in periodic solids lead to band gaps in semiconductors, which provide the basis for modern electronics. In a similar way, "forbidden" states can also be generated in dielectric periodic structures. The so called photonics band gaps enable completely new forms of light guidance in photonic crystals. Quantum dots and quantum wires are further quantum objects that play an important role in modern electronics.

Finally, advanced concepts such as quantum entanglement are touched upon, which is one of the key concepts for future quantum computing systems. Currently, such systems are being intensively explored as the most promising next generation of computers, data centers and telecommunication systems for artificial intelligence (AI) and multiple other applications.

Whereas the fundamentals are the focus of this course, the application of new material structures on the micro and nanoscale including 2-dimensional materials are covered as well, e.g. in organic light emitting diodes, ion-sensitive transistors, and nanophotonic systems exploiting plasmonic effects.

Aims, content, methods

Learning objectives and competencies to be acquired

After completion of this module the students will:

- know the fundamental aspects of quantum mechanics and understand the quantum nature of the nanoworld
- know the phenomena of nano-and microstructures influencing surface and material properties (e.g. structural colors, interferencial colors, tribo-mechanical and wetting behaviour)
- know the fundamental quantum mechanical concept of discretization and resulting consequences such as discrete energy states, electronic and photonic band gaps, quantum dots and quantum wires and their applications in modern photonics, electronics, and medicine
- know the basics of quantum entanglement and quantum computing
- know the interaction of light with dielectric, semiconductor and metallic nanoparticles (incl. plasmonics)

Module content with weighting of different components

- From macro to micro to nano: scaling of physical systems and the consequences (3 lessons)
- Nano- and microstructured surfaces: Surface Physics, Nucleation, Nano Tribology, Structural and interferencial colors, (6 lessons)
- Nanophotonics: Interaction of light with nanoparticles and nanostructures (dielectric, metallic, semiconductor) (3 lessons)
- Quantum mechanics and Quantum Nature of the Nanoworld: Particle-wave duality, Schrödinger equation, discrete energy levels, sizing effects (9 lessons)
- Quantum entanglement and quantum computing (3 lessons).
- Molecules, quantum dots and wires: OLEDs (organic light emitting diodes) and QLEDs for optoelectronics and ISFETs (ion-sensitive field-effect transistors) for biotechnology (6 lessons)
- Electronic and photonic bandgaps: Physical basics and applications (6 lessons)
- Photonic crystal and hollow core fibers (3 lessons)
- Origin of light and laser polarization (3 lessons)

Teaching and learning methods

Lectures and self-study

Practical exercises

Literature

Lecture notes, application oriented summary articles or slides with indication of sources for further reading will be distributed.

Introductory physics textbooks

Introduction to Nanoscience & Nanotechnology, Gabor L Hornyak et al. , CRC Press, 2009.

Nanophysik und Nanotechnologie, Edward Wolf, Wiley-VCH, 2014

Assessment

Additional performance assessment during the semester

The module does not contain an additional performance assessment during the semester

Basic principle for exams

As a rule, all standard final exams are conducted in written form. For resit exams, lecturers will communicate the exam format (written/oral) together with the exam schedule.

Standard final exam for a module and written resit exam

Kind of exam

Written exam

Duration of exam

120 minutes

Permissible aids

Aids permitted as specified below:

Permissible electronic aids

No electronic aids permitted

Other permissible aids

Personal formulary: four A4 pages (2 sheets doublesided or 4 sheets singlesided)

Exception: In case of an electronic Moodle exam, adjustments to the permissible aids may occur. Lecturers will announce the final permissible aids prior to the exam session.

Special case: Resit exam as oral exam

Kind of exam

Oral exam

Duration of exam

30 minutes

Permissible aids

Aids permitted as specified below:

Permissible electronic aids

No electronic aids permitted

Other permissible aids

Personal formulary: four A4 pages (2 sheets doublesided or 4 sheets singlesided)