Course Package

Applied Physics – 2A

Name module	Applied Physics - 2A
Educational programme	MSc Applied Physics
Period	First block of the second semester (block 2A)
Study load	15 ECTS

Applied Physics			
block 1A	***block 1B***	***block 2A***	**block 2B**
		Electives: choose 15 EC	
		Nano-Fluidics – 193400121 *(5 EC)*	
		Granular Matter – 201400194 *(5 EC)*	
		Surfaces and Thin Layers - 193550020 (5EC)	
		Integrated Photonic Systems and Experiments – 202200045 *(5 EC)*	
		Integrated Optics – 191210880 *(5 EC)*	
		Machine Learning – 202100224 *(5 EC)*	
		Computational Physics – 202100223 (5 EC)	
		Soft Matter Physics – 202001413 (5 EC)	
		Heat and Mass Transfer – 191470241 (5 EC)	
		Classical and Quantum Emitters - 202200048 (5 EC)	

Required preliminary knowledge: Completed Bachelor's (Applied) Physics; Fluid Mechanics; Finished Bachelor AM; AP or ME; or equivalent; Wave Optics; Laser Physics; and Nonlinear Optics; Electrodynamics; Electrodynamics or comparable courses; Python programming skills; Statistical Physics AT; or Statistical Physics TN; Fluid Physics TN MOD08 or similar knowledge; Electrodynamics; Quantum Mechanics 1.

Electives: choose 15 EC

193400121 - **Nano-Fluidics**

This course gives an introduction into Nano fluidics, considering fundamental aspects, intrinsic length scales and geometry. A number of different selected topics in the field of Nano fluidics are discussed, such as:

- basic fluid dynamics for micro- and Nano channels
- solid-liquid interfaces (interactions, adsorption/desorption)
- electric double layer theory
- hydrodynamics at small scales (laminar flow, slip versus no-slip, mixing)

- 3-phase systems (capillary forces, wetting, super hydrophobicity)
- electro kinetic effects (electroosmotic pumping, electro viscous effect)
- electrophoresis and separation techniques
- (Nano)colloidal particles and colloidal assembly

201400194 - **Granular Matter**

Granular Matter comprises all materials that consist of many particulate entities, each of which large enough not to be subject to thermal motion at room temperature. This somewhat technical definition comprises everyday materials such as sand, flour, gravel, snow, iron ore, and metal scrap. It is ubiquitous in nature, since mountains, soil and the bottom of the sea are predominantly granular. In industry, the most processed materials (with the exception of water) are in granular form, and problems with their handling are causing a staggering loss of 5% of the world energy budget (which corresponds to over 300 billion euros every year). In contrast to its obvious relevance the behaviour of granular materials remains poorly understood. Granular matter can be studied from a fundamental and an engineering perspective, commonly denoted as Granular physics and Particle Technology, respectively.

Because of the strong connection between the two subjects, this course aims at giving a basic introduction to both. Topics that will be covered are:

- particles, size analysis and characterization,
- contacts, inelasticity, restitution, and collision models,
- static granular materials, Rayleigh-Jansen law,
- Mohr-Coulomb and soil mechanics,
- dense flows and granular suspensions,
- granular gases and kinetic theory,
- micro/macro aspects and granular hydrodynamics,
- separation, mixing, and segregation,
- processing (granulation and fluidization),
- storage and transport,
- geophysical granular flows, chute flows.

193550020 - **Surfaces and Thin Layers**

The structure and (electronic) properties of both clean and adsorbate covered surfaces are described. The most common tools to study these phenomena, diffraction and scanning probe techniques are introduced in relation to the measured results. The adsorption and desorption of species from surfaces are described. Growth of thin films is an important part of this field and the thermodynamic and kinetic aspects of growth are discussed. The electronic structure of surfaces and thin films in relation to their properties is described. This course is part of the track Materials Science and is compulsory for students of this track.

202200045 - Integrated Photonic Systems and Experiments

The course will be divided into 2 major components.

In the first component, students will learn about basic integrated photonic systems, consisting of light sources, optical modulators, signal processing (using integrated photonic components), and detection of light. The course will discuss how system configuration affects functionality and signal quality.

In the second component, the students will study selected papers on the state-of the art integrated photonic systems for various applications, including, but not limited to, advanced light sources, signal processing, quantum photonics, computing, and precision sensing. Further the students will experimentally investigate one of the many aspects of photonic systems including:

- Intensity and phase noise sources
- Various modulation concepts and the resulting spectra
- Complex signal processing using integrated ring resonators

191210880 - Integrated Optics

Integrated optics is expected to become one of the key enabling technologies of the 21st century, helping to overcome the bottlenecks faces by current electronics. Several decades ago, optical fibers revolutionized the communication field, providing affordable connectivity between people in different parts of the world. A prime example is the wide spread of high-speed internet and mobile communications which was possible thanks to optical fiber technology. Integrated waveguides are on-chip versions of optical fibers. First proposed in the 1960's, integrated optical circuits are analogous to electronic integrated circuits. The main difference is that the information is processed in the form of "light" instead of by electrical signals, enabling therefore much higher transmission speed and processing capabilities. By selecting the correct set of materials, waveguiding structures, that confine and route light with dimensions in the micrometer and even nanometer scale, can be integrated on a chip. In this course, you will learn the foundations of the field “integrated optics" and you will acquire the necessary theoretical and practical skills required to design various integrated photonic devices. In lecture format, the basic principles covering the theory of planar waveguides, basic structures, non-linear optics, materials and technology, as well as an introduction into numerical methods and different commercial software tools will be discussed in the first half of the course. The theoretical knowledge acquired will form the basis for the solution of a number of practical assignments, executed using commercial design tools. During the final assignment you will perform the complete design and optimization of an integrated photonic device. The course evaluation is based on the student's written reports (exercises and final report). The following basic and modern topics, relevant for optical sensors, on-chip lasers and optical amplifiers, and telecommunication, will be treated:

- Theory of planar waveguides,
- Integrated Optics Basic structures,
- Beam Propagation Methods,
- Photonic Crystals, Plasmonic waveguides, Optical filters, Active Devices,
- Materials and technology,
- Fields of application include telecommunication, on-chip photonic devices for medical applications and optical sensors.

202100224 - Machine Learning

Machine Learning (ML) and Artificial Intelligence (AI) are fast expanding topics in mathematics (e.g., statistics, control), computer science, robotics, engineering and science in general. In the field of computational physics and chemistry ML is on the rise to learn simple models based on data produced by numerically solving complex equations on supercomputers.

This course will give you an overview on ML (and a little AI) and will let you learn the concepts in a ‘hands-on’ manner.

1. We start with
- 'programming in Python'. Do not worry if you have never programmed in Python: you will get Jupyter notebooks from level 0 up to the level that is required. Of course, you should have some affinity with programming;
- a little 'probability theory'. Algorithms can be analyzed, but methods in ML and AI look pretty ad hoc, especially when it comes to neural networks (deep learning). Statisticians claim that ML is in fact statistics.
2. The first few weeks we treat the basic ML topics on supervised, unsupervised and reinforcement learning. This leads to methods for classification, clustering, linear and nonlinear regression, searching (so a little AI as well);
3. In the second half of the course you will do a project: you can choose 'whatever' you like. This can be;
- building a neural network for some application,
- getting a deeper understanding of why certain algorithms (do not) work,
- joining in to a Kaggle competition problem,
- making a world champion (well, a very good) backgammon player,
- etc.

In any case, before you start on your project you should prepare a short project proposal (max. 1 A4) in which you write what you want to do, how you are going to do it and why you think this is the right strategy.

Please note: these packages are not fixed. They serve as an example of what you are able to select. It may be possible for you to make changes if you would like to do so.
The modules are tentative and subject to change. Please check the website *regularly.*

202100223 - Computational Physics

The Computational Physics course will illustrate through guided practical sessions how one solves physics problems on the computer. For a number of selected topics, the student will set up a computational "experiment". He/she will develop an appropriate computational strategy for each given problem, implement the needed numerical techniques, analyze the results and the correctness of the model regarding the chosen

computational parameters, and describe/interpret the physical phenomena.

Subjects in 2.5 EC Computational Physics part:

- Excitons – Numerical solution of the radial Schrödinger equation,
- Magnetism, Ising model – Monte Carlo simulations.

Additional Subjects for the expansion to the 5.0 EC Computational Physics:

- Wave propagation – Transmission of electron waves through (resonant) tunneling devices,
- Non-linear and linear physics problems – Poisson-Boltzmann equation, eigenvalue problems, molecular Rotations,
- Diffusion – Brownian motion, random walks.

202001413 - **Soft Matter Physics**

This course introduces the main concepts underlying the physical description of 'soft' systems such as Brownian motion and thermal fluctuations. These are illustrated with examples from the main classes of soft matter including solutions, polymers, and surfactants. Key experimental techniques such as light scattering and rheology are also discussed.

191470241 - **Heat and Mass Transfer**

Foundations of heat and mass transfer. Stationary and instationary guidance. Radiation. Dimension analysis. Forced and free convection, both in internal and external configurations. Latent heat in phase transitions: boiling, evaporation, condensation, solidification. Modeling in practical situations.

202200048 - **Classical and Quantum Emitters**

In this course in the Optics and Biophysics Track, we discuss the optical properties of three main classes of elementary light sources that are used in wide range of optical and biophysical applications. We focus on (a) atoms, (b) molecules, and (c) quantum dots and quantum wells, and analyze their emission in terms of spectra and time-resolved rates. We review the essential quantum mechanics, including static and time-dependent perturbation theory, the variational principle. We also review the complete radiation properties of a classical dipole, including field behavior relevant to near-field effects.

We discuss in-depth 3 classical and quantum views on spontaneous emission: antennae, circuits, fields, leading to Fermi's golden rule, selection rules for optical transitions. We investigate the optical properties of an atom, including in an external field. We discuss molecular bonding, and electronic and vibrational transitions in molecules to arrive at fluorescence. After a brief review of the electronic and optical properties of a semiconductor, we study semiconductor quantum wells. We discuss semiconductor quantum dots that are also considered as flexible man-made "artificial atoms", and that are popular in myriad fields ranging from nanophotonics, lasers, telecom, to photovoltaics and biomedical labeling.