I. General

This course is primarily based upon the textbook:

C. Kittel: Introduction to Solid State Physics, 8th ed., Wiley, 2005.

These Lecture notes are intended as a complement to the book. References to the contents of the course book are continuously given in the notes below. Part of the additional material has been adapted from earlier Lecture notes at this Institute or from the books:

H.P. Myers: Introductory solid state physics, Taylor and Francis, London, 1990.
S.R. Elliott: The physics and chemistry of solids, Wiley, 1998.

II. Introduction: What is Solid State Physics?

Solid state physics is the physics of solid substances. They can be divided into different kinds: single crystals, polycrystalline materials, fractal materials and amorphous materials. In this course we will mainly consider the crystalline solids. Their physical properties are the easiest to describe, because of the regular structure. Hence they constitute a good starting point for a study of solid state physics.

A single crystal consists of a regular three-dimensional pattern of atoms (Kittel, Ch.1, Fig.1, Fig.17). Only a limited number of basic crystal structures are possible to obtain. A polycrystalline material consists of an assembly of small single crystals separated by narrow, more disordered grain boundaries. The crystalline size may vary from nanometers to micrometers and even mm, depending on preparation conditions and techniques.

Now there are no perfect crystals; defects (vacancies, interstitials…) are necessary for thermodynamic reasons (Kittel, Ch. 20). The grain boundaries can also be viewed as defects, see Kittel, p. 607 for an illustration. In addition is it hardly possible to avoid impurities.

Amorphous materials (Kittel, Ch. 19) exhibit a disordered or even random atomic structure. Nevertheless they are frequently of technological interest. Fractals are a class of materials that exhibit dilation symmetry, i.e. they look similar when viewed with different magnification! We will not treat defects and non-crystalline materials further in this course.

Condensed matter physics is a wider subject than solid state physics – it includes also the physics of liquids and liquid crystals.

In this course we will study simple models of the properties of crystalline solids. They give a good picture of what to expect in reality. The physical properties of solids are caused by the behaviour of the ions (by this we mean the atomic nucleus with inner electrons in closed shells), the electrons (the valence ones) and/or defects. The basis for the models that we will study lies in the atomic structure and the electronic structure of crystalline solids.

The materials: Metals
Semiconductors
Insulators

Phenomena: Crystalline structure
Atomic vibrations, thermal properties
Electronic structure, electrical and optical properties
Superconductivity
Magnetism

Variables: We measure often a property as a function of certain variables.
Temperature (mK-3000 K)
Energy (provided by photons, neutrons, electrons or ions)
Pressure (10^{-10} to 10^{10} Pa)
Magnetic field (-50 T)
Electric field (- 1 GV/m)

In particular the spectroscopic techniques that measure material properties as a function of energy (or frequency) are very suitable for studies of a wide range of phenomena including atomic structure, atomic vibrations, electronic structure, electrical and optical properties.

Motivation: Solid state physics is the prerequisite for a wide range of technological applications. The present course gives the basics needed for many fields of applied science. Fields of applied science and technology that depend on solid state physics include:

Materials science (applications of mechanical, electrical, optical, magnetic…properties of solids).
Semiconductor technology and micro-electronics (including opto-electronics).
Microstructure engineering, nano-technology (in solids with small dimensions new phenomena can appear).
Energy technology (solar cells, optical coatings for windows, solar collectors, batteries).

Inorganic chemistry (the border between physics and chemistry is breaking down!).
Biological materials, biomimetics (there is an increasing interest to study biological matter by physical methods).
Pharmaceutical materials science.
Medical technology (X-ray, NMR…).

We should not forget the important fields of instrument and measurement technology and the field of information storage (optical and magnetic storage).

The field of solid state physics can be pictured as a table with four legs. All of them are necessary if the table is to be stable. They are: Basic research, applied research, theory and applications.