Solid State Physics

"The heart of the technological revolution!"

The aim is to bring the following three things together:

- Atoms
- Quantum Mechanics
- Statistical Physics

We look at:

- Crystalline materials
- Amorphous materials (e.g. glass, plastic)
- Liquids

All three of these fall under condensed matter. The first two are solid state. We will be focusing on crystalline materials in this course.

Example Properties of Crystals:

- Transition temperatures, e.g. the melting point of a material
- Mechanical properties, e.g. strength, elasticity, etc.
- Electrical properties, e.g. conductivity, piezzo-electric effects, thermoelectric effects, …
- Magnetic properties, e.g. susceptibility
- Thermal properties, e.g. heat capacity
- Optical properties, e.g. reflectivity, colour, etc.

e.g. Iron:

- One of the most complicated in terms of magnetics.
- - $T_{melting} = 1808k$
- Two different crystal structures (fcc [stainless steel], bcc [magnetic])
- Reflects visible light
- Conducts electricity. Resistivity $10^{-5}\Omega cm$ at room temperature
- Ferromagnetic $T < T_c = 1043k$
- Low temperature specific heat $C = \gamma T + \varepsilon T^{3/2} + \beta T^3$, where the last term comes from the Debye model, the first from electron gases, and the middle from the disturbances in the magnetic order.

NB: in classical physics, you can't have a magnetic dipole in the absence of a magnetic field. You can only get this through quantum mechanics.

Aim of the course:
We have 10^{23} atoms or more. It is fundamentally a many body problem. There are no exact solutions. We will develop approximation schemes and the associated physical pictures (models), which will help us to think about what is going on.

Taking the example of the low-T specific heat of iron, we will start from the structure of a perfect infinite crystal at $T = 0$. We know that this is incorrect, but it is a starting point. We will add in some lattice vibrations, which will give us the T^3 term in the specific heat. We will then look at the fact that electrons are free to travel, which will give us the T term. We will then look at the potential arising from the other electrons, which is a tricky problem, and thus get a better value for γ. Following this, we will put in the electron spin (the cause of magnetism), actually the spin waves (the collective actions of the magnetic moments in wavelike form), which will give us the $T^{3/2}$. We will then assume that the specific heat from each of these elements can be added up to get the overall heat capacity (which is not trivial).

Outline of the course (H&H):

1. Crystal Structures (1.1-1.3)
2. Diffraction and the Reciprocal Lattice (11.1, 11.2, 12.1-12.3)
3. Lattice Dynamics (2.1-2.6, 12.4)
4. Metals (3, 4)
5. Semiconductors (5)

Books:

- *Solid State Physics*, Hook & Hall, Manchester Physics Series, Wiley 2nd edition, 1991. (need 2nd edition, not 1st).
  Chapters 1-5, and parts of chapters 11 and 12.
- *Introduction to Solid State Physics*, Kittel, 8th edition, 2004.
  (5th edition onwards OK)
  Chapters 1-8

Follow-up courses:

- PC 4451 Superconductors & Superfluids
- PC 4752 Frontiers of Solid State Physics (advanced semiconductors, low-dimensional systems [systems which do not have the full dimensionality of the space we live in], mesescopic physics [nanotechnology])