The following is an overview of the material from the lecture course that you should be familiar with for the exam. Note **all** material covered has been designed to give a good grounding in Condensed Matter Physics and will be called upon in later courses of your degree programme, projects, or placements.

Numbers in square brackets denote particularly relevant questions, with $h.k$ indicating question k from problem sheet h.

Crystal Structure

- Given a 2D crystal structure be able to identify/name the Bravais lattice, primitive vectors, unit cell (inc. Wigner-Seitz), and basis. [1.1, 1.2]
- For the sc, fcc, bcc and CsCl 3D crystal structures, be able to sketch atoms in conventional unit cell, state basis, calculate nearest-neighbour distances, and perform calculations relating atomic structure to macroscopic data (no. of atoms, mass density, conduction electron density). [1.4, 1.6, 2.6]
- For cubic crystals, be able to extract basis from sketch of conventional unit cell, and vice versa. [1.7,2.5(iii)]
- Be familiar with $[hk\ell]$, $\langle hk\ell\rangle$, $(hk\ell)$ and $\{hk\ell\}$ notation and able to use them; be able to sketch directions and important planes in cubic lattices. [1.8, 1.9]
- Be familiar with Bragg's law, and able to analyse diffraction data to distinguish different crystal structures. (The formula for plane spacings in sc, fcc, and bcc would be given in exam.) [2.1, 2.2, 2.3]
- Be familiar with the basic physics of X-rays, neutrons, and electrons relevant to structure determination, incl. how they influence choice of probe. (Familiarity with the Periodic Table of the Elements is not expected.) [2.4]
- Be familiar with the scattering vectors Q, Laue conditions and structure factor and their role in diffraction (detailed derivations not required). [2.5]

Electrons in solids

- Be familiar with the concept of the scattering time τ and the equation of motion in the Drude model; its application to DC conductivity; the concept of the drift velocity; and the relationship between the conductivity and resistivity. [2.7, 2.8, 2.9, 2.10]
- *Thermal conductivity/Wiedemann-Franz Law will **NOT** be examined*
- Be familiar with the physics of the Hall effect and its analysis, including derivation of the Hall coefficient and how it can be measured. [2.11]
- Be familiar with periodic boundary conditions and wave vector quantisation; the concept of the Fermi sphere; the terms Fermi wave vector, Fermi energy, and Fermi temperature; and be able to derive the relationship between the Fermi wave vector and the free electron density. [3.1, 3.2, 3.3]
- Be familiar with the concept of the density of states $g(\epsilon)$ & density of occupied states $g(\epsilon)f(\epsilon)$. Be able to derive an expression for $g(\epsilon)$, and use it to determine the Fermi energy, total energy, and electron speeds. [3.1, 3.3]
- Be familiar with the classical predictions of the electronic heat capacity, and the simple arguments for the behaviour of the low T heat capacity within the Sommerfeld model. [3.4, 5.8]
- Be familiar with the effects of an electric field, scattering and thermal excitation within the Fermi sphere picture.
- Be familiar with Bloch's theorem *Derivation/recall of definition **NOT** required*.
- Be familiar with the qualitative effect of a weak periodic potential on free-electron energy bands, and wave functions/probability densities of states above & below a gap at the zone boundary.

- Be familiar with the no. of states in a band, and the significance of a band being full; the distinction between the energy bands and density of states of metals, semiconductors, and insulators. [3.5]
- Be familiar with the group velocity of a band electron and the concept of effective mass (derivation **NOT** required), and able to evaluate electron/hole masses from expressions for energy bands. [3.5]
- Be familiar with the equations of motion of electrons and holes in a band.

Semiconductors

- Be able to distinguish between direct and indirect semiconductors, intrinsic and extrinsic semiconductors, and be familiar with the concept of holes and their properties. [3.5 (part)]
- Be able to follow the derivation of the carrier densities in an intrinsic semiconductor (recall **NOT** expected). Given expressions for n and p, be able to explain how gaps can be determined from measurements of carrier densities at different temperatures, and how the Fermi energy/chemical potential varies with T. [3.6]
- Be familiar with the use of cyclotron resonance to determine electron and hole masses in semiconductors.
- Be familiar with the concept of n- and p-type doping in extrinsic semiconductors, and the Hydrogen model applied to each (recall of standard results from H atom **NOT** expected). Know typical magnitudes and locations of donor levels in doped semiconductors, and the typical size of donor level orbital radii. [3.7]
- Be familiar with the effects of doping on the location of the Fermi level, and the physics underlying the T-dependence of the carrier density in doped semiconductors. [3.8]

Magnetism

- Be able to state the basic origin of paramagnetism, diamagnetism, ferromagnetism, and the temperature dependence of the associated magnetic susceptibility [4.1]
- Be able to derive the magnetisation of a $S = 1/2$ paramagnet, analyse $\mathcal{M}(\mathcal{B}, T)$ expressions to deduce the weak field magnetic susceptibility, and be able to briefly describe the adaptation of the model to ferromagnetism. [4.2(ii)]
- Be familiar with the classical theory of diamagnetism.
- Be able to perform a graphical analysis of the spontaneous magnetisation in a $S = 1/2$ ferromagnet given a plot of $y = \tanh x$. [4.6]

Crystal Dynamics

- Be able to derive and interpret the dispersion relation $\omega(k)$ of lattice waves in monatomic chains. Be able to *interpret* the dispersion relation of diatomic chains [derivation **NOT** required] and know the characteristic atomic motions and associated properties. Be able to deduce the long-wavelength limit of dispersion relations. [5.1, 5.2, 5.6(i, ii, iii)]
- Be able to understand and use the following terms in the context of lattice vibrations: cut-off frequency, Brillouin zone, longitudinal, transverse, group velocity, phase velocity, speed of sound, branch, phonon, acoustic, optical.
- Be familiar with the use of scattering experiments to probe lattice vibrations.
- Be able to interpret dispersion curves for real solids. [5.2, 5.3]
- Be familiar with the underlying assumptions and key predictions of the classical, Einstein and Debye theories of heat capacity. [5.7]
- Be able to deduce high and low temperature behaviour given $C_V(T)$ expression (Einstein) or integral (Debye). Recall of expression/integral **NOT** expected.
- Be able to analyze low-temperature heat capacity data (recall of detailed expressions is **NOT** expected). [5.9, 5.10, 5.11]