Problem Sheet 5
Solid State Theory
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Problem 1) **(4 Points)**

Indium antimonide has the energy gap $E_g = 0.23\,\mathrm{eV}$, the dielectric constant $\epsilon = 18$ and the electron effective mass $m_e = 0.015\,\mathrm{m}$.

(a) Calculate the donor ionization energy.

(b) Calculate the radius of the ground state orbit.

(c) At what minimum donor concentration will appreciable overlap effects between the orbits of adjacent impurity atoms occur?

This overlap tends to produce an impurity band - a band of energy levels which permit conductivity presumably by a hopping mechanism in which electrons move from one impurity site to a neighboring ionized impurity site.

Problem 2) **(4 Points)**

Consider the energy surface

$$\epsilon(\vec{k}) = \hbar^2 \left(\frac{k_x^2 + k_y^2}{2m_t} + \frac{k_z^2}{2m_l} \right), \tag{1}$$

where m_t is the transverse mass parameter and m_l is the longitudinal mass parameter. A surface on which $\epsilon(\vec{k})$ is constant will be a spheroid. Use the equation of motion, Equation (6) from Lecture 8, with $\vec{v} = \hbar^{-1}\nabla_{\vec{k}}\epsilon$, to show that $\omega_c = eB/(m_l m_t)^{1/2}c$ where $B = |\vec{B}|$ when the static magnetic field $\vec{B}$ lies in the x-y-plane.

Problem 3) **(4 Points)**

An open orbit in a monovalent tetragonal metal connects opposite faces of the boundary of a Brillouin zone. The faces are separated by $G = 2 \times 10^8\,\mathrm{cm}^{-1}$. A magnetic field $B = 10 \times 10^3$ gauss $= 1 \times 10^{-1}$ tesla is normal to the plane of the open orbit.

(a) What is the order of magnitude of the period of the motion in $\vec{k}$ space? Take $v \approx 1 \times 10^8\,\mathrm{cm\,s}^{-1}$.

(b) Describe in real space the motion of an electron on this orbit in the presence of the magnetic field.