Condensed Matter II

Problem set #6

Spring 2023

1 Cyclotron resonance of electrons and holes

In this section, we extend the description of cyclotron resonance to an anisotropic band structure with the following dispersion relation, with m_l and m_t the longitudinal and transversal effective masses.

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

The magnetic field is assumed to lie in the (x, z) plane, making an angle θ with the longitudinal axis:

$$\vec{B} = B_0(\sin\theta, 0, \cos\theta)$$

(i) Give the expression of the effective Hamiltonian, as a function of m_l and m_t.

(ii) Working in the semiclassical framework, establish the equation of motion obeyed by the particles, assuming that the fields evolve as $\exp(i\omega t)$.

(iii) Deduce a condition on ω, under which a finite value of $\vec{P}$ may exist in the material.

(iv) Discuss how this could be used in order to determine m_l and m_t experimentally.

2 Donor states in III-V compounds

In the litterature, you may find the following values for the effective mass, the dielectric constant and the experimental binding energy of shallow donors:

- GaAs: $m = 0.07m_0$, $\epsilon = 12.5$, $E_e = 5.8\,\mathrm{meV}$
- InSb: $m = 0.014m_0$, $\epsilon = 16.8$, $E_e = 0.6\,\mathrm{meV}$

Use these values in the hydrogenic donor state model, and compute the ionization energy of the ground state in this model. Compare with experimental data.