Unkonventionelle Supraleitung

Serie S1

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Multiple superconducting phase transitions.

S1 We consider a system described by the following Ginzburg-Landau free energy density f with two-component superconducting order parameter $\vec{\eta} = (\eta_x, \eta_y)$.

$$f = a'(T - T_c)|\vec{\eta}|^2 + b_1|\vec{\eta}|^4 + \frac{b_2}{2}\{\eta_x^{*2}\eta_y^2 + \eta_x^2\eta_y^{*2}\} + b_3|\eta_x|^2|\eta_y|^2,$$

where the coefficients a' (> 0) and b_i $(i = 1, 2, 3)$ are real numbers. we take $b_1 > 0$.

Let us investigate the situation that a symmetry reduction of the above system occurs, lifting the degeneracy of the two components η_x and η_y. Then, the second order term of f changes:

$$a'(T - T_c)|\vec{\eta}|^2 \quad \rightarrow \quad a'(T - T_{cx})|\eta_x|^2 + a'(T - T_{cy})|\eta_y|^2.$$

[See Eq. (4.29) or (181) in the theory lecture notes.] Here, we assume that the degeneracy lifting is small such that T_{cx} and T_{cy} are only slightly different, i.e., $|T_{cx} - T_{cy}| \ll T_{cx}, T_{cy}$. We assume $T_{cx} > T_{cy}$.

The first superconducting transition occurs at $T = T_{cx}$. That is, $\vec{\eta} = (0, 0) \rightarrow \vec{\eta} = (\eta_x, 0)$ at $T = T_{cx}$. Then, the second transition from this phase $\vec{\eta} = (\eta_x, 0)$ to lower-temperature phase $\vec{\eta} = (\eta_x, \eta_y)$, occurs at $T = T'_{cy}$ $(< T_{cx})$. It is known that T'_{cy} *is different from* T_{cy}.

Problem: Show that the second transition temperature T'_{cy} is given by

$$T'_{cy} = \max\{T_{y+}, T_{y-}\},$$

where

$$T_{y\pm} = T_{cy}\frac{1 - R_\pm T_{cx}/T_{cy}}{1 - R_\pm}, \qquad \text{with} \qquad R_\pm = 1 + \frac{b_3 \pm b_2}{2b_1}.$$

[See Eq. (4.35) or (188).]