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14. Abstract/Notes

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RESISTIVITY OF A DISORDERED 2-D ELECTRON GAS IN TERMS OF FORCE-FORCE CORRELATION FUNCTION

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The lowest order diagram in a perturbative expansion of the force-force correlation function for a 2-D electron gas under strong magnetic field is used to calculate its resistivity.

It has been shown recently by Ying and da Cunha Lima /1/ and also by Shiwa and Isihara /2/ that transport properties of disordered electronic systems can be obtained via a memory function-projection operator formalism. A review of the theory is shown as a talk in this symposium.

In this work the resistivity of a 2-D electron gas under a strong magnetic field is obtained in the lowest order of a diagrammatic perturbation expansion of the force-force correlation function. The starting point is the equation for the resistivity matrix (2x2).

$$\overline{\underset{\sim}{\rho}}(\omega) = - \frac{im_o}{Ne^2} [\omega \underset{\sim}{I} - \underset{\sim}{\Omega} + \overline{\underset{\sim}{M}}(\omega)], \qquad (1)$$

where m_o is the electron effective mass, e is its charge and N is the number per unit area, $\underset{\sim}{I}$ is the unit matrix. The bar refers to average on all impurities configurations. $\underset{\sim}{\Omega}$ is defined as

$$\underset{\sim}{\Omega} = -iNm_o\omega_c \begin{pmatrix} 0 & 1 \\ -1 & 0 \end{pmatrix} \qquad (2)$$

where ω_c is the cyclotron frequency. $\underset{\sim}{M}(\omega)$ is the memory function, expressed in terms of the retarded force-force correlation function $\pi^R_{\alpha\beta}(\omega)$, $\alpha, \beta = x, y$:

$$M_{\alpha\beta}(\omega) = - \frac{1}{Nm_o\omega} [\pi^R_{\alpha\beta}(\omega) - \pi^R_{\alpha\beta}(0)], \tag{3}$$

where

$$\pi^R_{\alpha\beta}(\omega) = -i \int_{-\infty}^{+\infty} \Theta(t) < [U_\alpha(t), U_\beta(0)] > e^{i\omega t} dt. \tag{4}$$

In the equation above U_α is the α-projection of the generalized force acting on the center of mass of the 2-D electron system due to scattering by impurities:

$$U_\alpha = \sum_{\vec{q},l} iq_\alpha \, e^{i\vec{q}x\vec{R}_l} \, U(q) \, \rho(\vec{q}), \tag{5}$$

where $\rho(q)$ is the density operator, i.e., $\rho(q) = \sum_j e^{i\vec{q}.\vec{r}j}$.

For low impurity concentration $\overline{\pi}^R_{\alpha\beta}(\omega)$ can be written as

$$\overline{\pi}^R_{\alpha\beta}(\omega) = n_i \sum_{\vec{q}} q_\alpha \, q_\beta U^2(\vec{q}) \, \overline{S}(q,\omega), \tag{6}$$

where $S(q,\omega)$ is the density-density correlation function. Then

$$\overline{\rho}_{xx}(\omega) = - \frac{im\omega}{Ne^2} + \frac{1}{N^2e^2} \frac{1}{\omega} \, \pi_{xx}(\omega), \tag{7}$$

$$\overline{\rho}_{xy}(\omega) = \frac{m\omega_c}{Ne^2} + \frac{1}{N^2e^2} \frac{1}{\omega} \, \overline{\pi}_{xy}(\omega),$$

with $\bar{A}(\omega) \equiv \overline{A}(\omega) - \overline{A}(0)$.

The force-force correlation function can be expressed in terms of finite-temperature Green's function

$$g(\vec{r} \, , \vec{r} \, ; \varepsilon) = \sum_{n,ky} \Psi_{n,k,y}(\vec{r}) \, \Psi_{n,ky}(\vec{r}_2) \, G(n,k_y; \varepsilon); \tag{8}$$

with $G(n,k_y, \tau)$ for the Landau quasi-particle propagator in the self--consistent Born approximation (SCBA) given by,

$$G_R\,(n,\,ky;\,\varepsilon) = (\varepsilon - E_n + i/2\tau)^{-1},$$
$$G_A\,(n,\,k_y;\,\varepsilon) = (\varepsilon - E_n - i/2\tau)^{-};\ E_n = \omega_c(n + 1/2), \tag{9}$$

and

$$\Psi_{n,ky}(\vec{r}) = e^{ik_yy}\,\phi n(x/\alpha + \alpha k_y),$$
$$\phi_n(\zeta) = (\sqrt{\pi}\,2^n\,n!\alpha)^{-1/2}\,H_n(\zeta)\quad e^{-\zeta 2}/2, \tag{10}$$

where $\Psi_{n,ky}$ is the eigengunction corresponding to the Landau level (n,ky); $\alpha = (m_o\,\omega_c)^{-1/2}$ and $H_n(\zeta)$ are the Hermite polynominal of order n.

Defining

$$J_{nm}(q,\,k_1,\,k_2) = \int dx\; e^{iq_xx}\;\phi_n(x/\alpha + \alpha k_1)\;\phi_m(x/\alpha + \alpha k_2), \tag{11}$$

the lowest order diagram in the expansion of $\overline{\pi}_{\alpha\beta}$(Fig.1) in the Matsubara representation is given by

$$\overline{\pi}^{o}_{\alpha\beta}(i\Omega) = \frac{u^2 p}{(2\pi)^2}\int d^2\,q\;q_\alpha\;q_\beta\sum_{mn}\left|\,j_{mn}(q_x,\,0,\,q_y)\right|^2 \times$$
$$\times\frac{1}{\beta}\sum_{i\omega} G(n,\,i\omega)\;G(m,\,i\omega - i\Omega). \tag{12}$$

We have assumed delta function scattering potential, $u^2{=}N_iU^2(q)$. The degeneracy of each Landau level is $p = m_o\omega_c/2$. The retarded correlation function $\overline{\pi}^{R}_{\alpha\beta}(\Omega)$ is obtained from (12) after the analytic continuation $i\Omega \to \Omega + io^+$. Performing the integral on $\vec{q}$, we obtain

$$\frac{1}{(2\pi)^2}\int d^2q\;q_x^2\;\left|\,J_{mn}(q_x,\,o,\,q_y)\right|^2 = (E_m + E_n)/\omega_c\alpha^2,$$
$$\frac{1}{(2\pi)^2}\int d^2_q\;q_x\;q_y\;\left|\,J_{nm}(q_x,\,o,\,q_y)\right|^2 = 0. \tag{13}$$

Then we can make a separation of variables m and n and perform the summation on each Landau level. Since we have assumed the SCBA, the density of states for the noninteracting, zero field electron gas becomes

$$N_1(\varepsilon) = (2\pi u^2\tau)^{-1}. \tag{14}$$

With this result the memory-function becomes

$$\overline{M}^{o}_{xy}(o) = 0,$$

$$\overline{M}^{o}_{xx}(o) = iN^{-1}E_F N_1(E_F)\tau^{-1}.$$

In the limit of zero magnetic field the memory function reproduces Drude's model:

$$\lim_{H\to 0} \overline{M}^{o}_{xx}(0) = i\tau^{-1},$$

$$\overline{\rho}_{xx}(\omega) = -\frac{im_o}{Ne^2}[\omega + i\tau^{-1}].$$

This result consist in a good test for the theory. The next step is to calculate higher order terms involving Coulomb interaction and vertex corrections. They should lead to terms on $\ln(\Omega\tau)$. The calculations are on progress.

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