1. In the theory of Miller-Abrahams hopping network, the transition rate for phonon absorption was determined to be

\[ \Gamma_{12} = \gamma_{12} \, e^{-\frac{2\pi}{\alpha}} \left[ 1 - f(\varepsilon_j) \right] N(\varepsilon_j - \varepsilon_i), \quad \text{where} \]

\[ f(\varepsilon_j) = \frac{1}{e^{\frac{\varepsilon_j - \mu}{T}} + 1}, \quad N(\varepsilon) = \frac{1}{e^{\frac{\varepsilon}{T}} - 1}. \]

Similarly, for transition rate with phonon emission we obtained

\[ \Gamma_{21} = \gamma_{21} \, e^{\frac{2\pi}{\alpha}} \left[ \frac{1}{1 - f(\varepsilon_i)} \right] \left[ \frac{1}{N(\varepsilon_j - \varepsilon_i) + 1} \right]. \]

Out of equilibrium, we have \( \varepsilon_j \to \varepsilon_j + \delta\varepsilon_j \) and \( \mu \to \mu + \delta\mu_j \) in \( f \)'s. Prove that to the lowest order in \( \frac{\delta\mu + \delta\varepsilon_j}{(-e)} \), the net current \( I_{1 \to 2} = (-e) \cdot (\Gamma_{12} - \Gamma_{21}) \) is given by:

\[ I_{1 \to 2} = \frac{U_1 - U_2}{R_{12}}, \quad R_{12} = \frac{T}{e^2 \gamma_{12}}, \quad \Gamma_{12} = \gamma_{12} \, e^{-\frac{2\pi}{\alpha}} \frac{1}{T}, \]

\[ \Delta = \frac{|\varepsilon_j - \varepsilon_i| + |\varepsilon_i - \mu| + |\varepsilon_j - \mu|}{2} \quad \text{for the case} \quad \Delta \gg \frac{T}{e}. \]

2. The equation of the effective medium theory for inhomogeneous conductor reads \( \left\langle \frac{\delta m - \delta(r)}{\delta(r) + (d-1)\delta m} \right\rangle \). Prove that for weakly inhomogeneous case \( \delta(r) = \langle \delta \rangle + \delta\varepsilon, \quad \delta\varepsilon \ll \langle \delta \rangle \), the solution for \( \delta m \) is

\[ \delta m = \langle \delta \rangle - \frac{1}{d} \cdot \frac{\langle \delta \varepsilon \rangle}{\langle \delta \rangle} + o(\delta\varepsilon^2), \quad \text{i.e., the EMT agrees with the perturbation theory}. \]