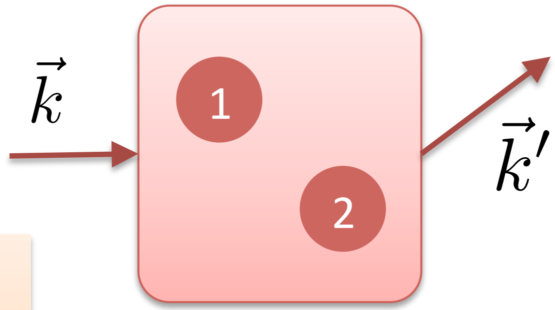
Matthiessen's rule

combining different scattering processes

$$W(\vec{k},\vec{k}') = W_1(\vec{k},\vec{k}') + W_2(\vec{k},\vec{k}')$$



scattering process are independent

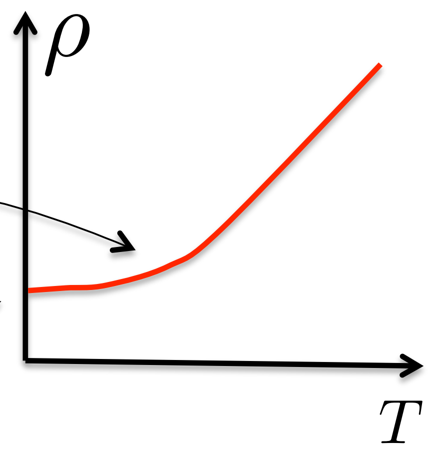
$$\frac{1}{\tau} = \frac{1}{\tau_1} + \frac{1}{\tau_2} \quad \Rightarrow \quad \rho = \frac{m}{ne^2\tau} = \rho_1 + \rho_2$$

"resistors in series"

Impurities + phonons + ...

$$\rho(T) = \rho_0 + \rho_{ep}(T) + \cdots$$

$$= \rho_0 + \alpha T^5 + \cdots$$



general

$$\rho \geq \rho_1 + \rho_2$$

e.g.: 1D system

$$R = R_1 + R_2 + \frac{2e^2}{h} R_1 R_2$$

Ioffe-Regel limit - maximal resistivity ?

mean free path

$$\ell = v_F \tau(\epsilon_F)$$

$\vec{k} \rightarrow \vec{k}'$ scattering

meaningless if ℓ shorter than electron wave length

natural limit

$$k_F \ell \sim 1$$

empirical formula

$$\frac{1}{\rho(T)} = \frac{1}{\rho_{BT}(T)} + \frac{1}{\rho_{\max}},$$

Boltzmann transport — Ioffe-Regel limit

with $\rho_{\max}$

$$\rho_{\max} = \frac{m}{e^2 n \tau} = \frac{3\pi^2 m}{e^2 k_F^3 \tau}$$

$$= \frac{h}{e^2} \frac{3\pi}{2 k_F^2 \ell} \sim \frac{h}{e^2} \frac{3\pi}{2 k_F}$$

standard metals

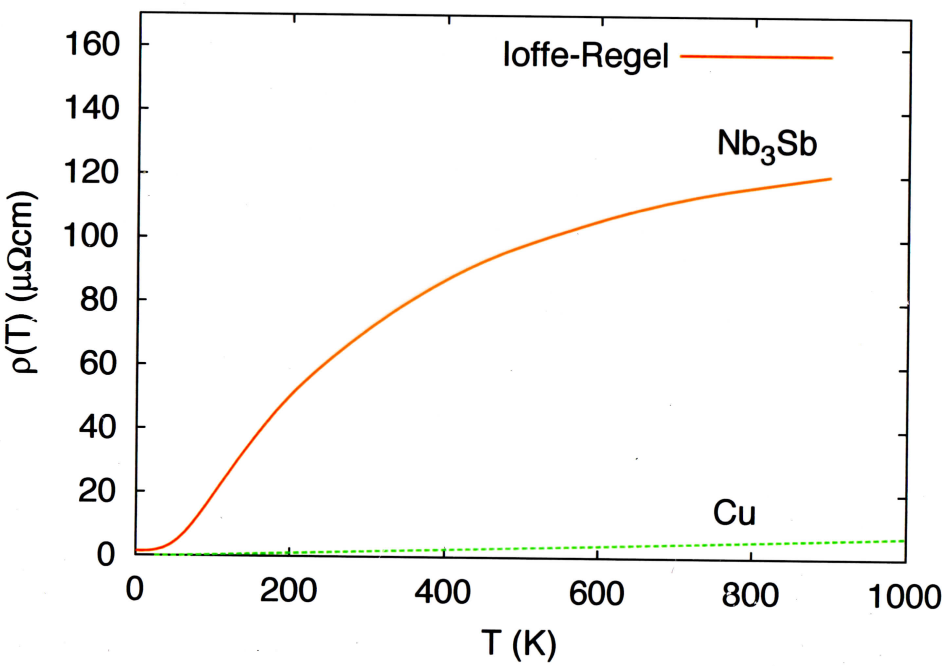
$$k_F \sim 10^8 \mathrm{cm}^{-1}$$

$$\rho_{\max} \sim 1 \mathrm{m}\Omega\mathrm{cm}$$

resistivity of metals at room-temperature

metal	$\rho[\mu\Omega\mathrm{cm}]$	metal	$\rho[\mu\Omega\mathrm{cm}]$
Cu	1.7	Pt	10.5
Au	2.2	Al	2.7
Ag	1.6	Sn	11

Ioffe-Regel limit - maximal resistivity ?



Ioffe-Regel limit obeyed

Cu: far below the limit

Nb_3Sb: saturation towards limit

Ioffe-Regel limit violated

both systems exceed limit for

all temperatures above

superconducting transition temperature