LECTURE # 38

Note Title 4/22/2009

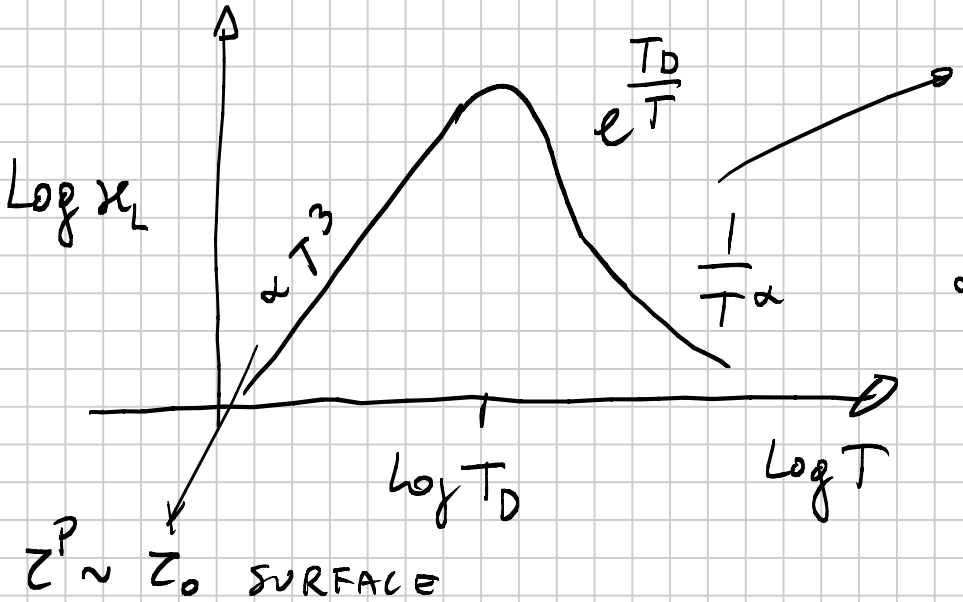
THERMAL CONDUCTIVITY

PHONONS

$$\kappa^L = \frac{1}{3} v_s^2 C_V^L \tau^P$$

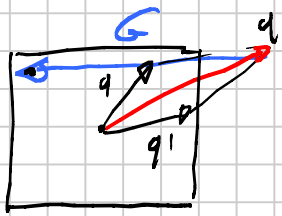
ELECTRONS

$$\kappa^e = \frac{1}{3} v_e^2 C_V^e \tau$$



UMKLAPP PROCESSES ACTIVATED

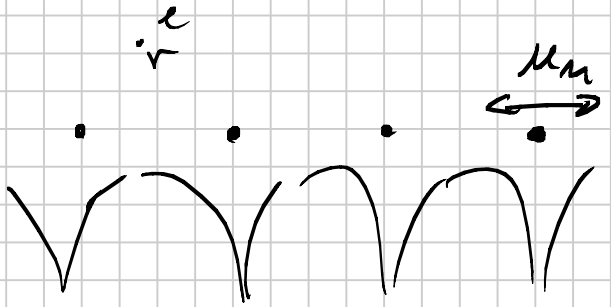
$\alpha \approx 1$



ELECTRIC CONDUCTIVITY σ

FOR BLOCH ELECTRON IS ∞

$\sigma = \infty$ ($\rho = 0$)



$$V_B^{IONS}(r) = \sum_{R_m} V_{AT}(\vec{r} - R_m)$$ (BLOCH THEORY — POTENTIAL USED)

ACTUAL POTENTIAL IS:

$$V(r) = \sum_{\vec{R}_m} V_{AT}(\vec{r} - \vec{R}_m - \vec{u}_m)$$

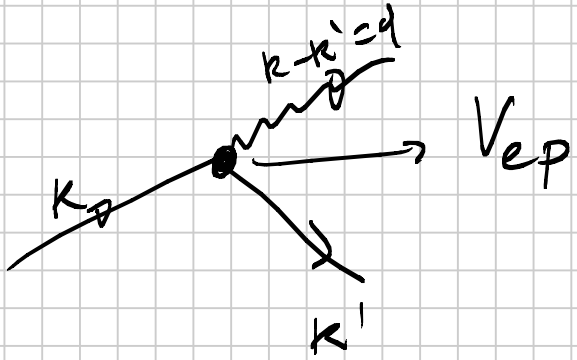
V_B^{IONS}

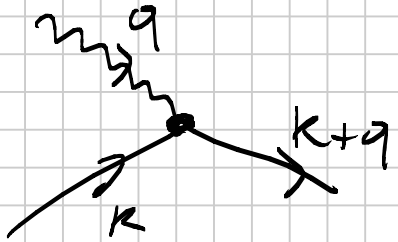
$$V(r) = \left[\sum_{\vec{R}_m} V_{AT}(\vec{r} - \vec{R}_m)\right] - \sum_{\vec{R}_m} \vec{u}_m \cdot \vec{\nabla} V_{AT}(\vec{r} - \vec{R}_m) + \cdots$$

INTERACTION BETWEE PHONONS & ELECTRONS $= V_{ep}$

$$x = a + a^{\dagger}$$

$$\vec{u}_m = \sum_q \frac{1}{\sqrt{2M\hbar\omega(q)}} \left(a_q^{\dagger} + a_q\right)$$





PHONON EMISSION

COMING FROM ∇V_{at}

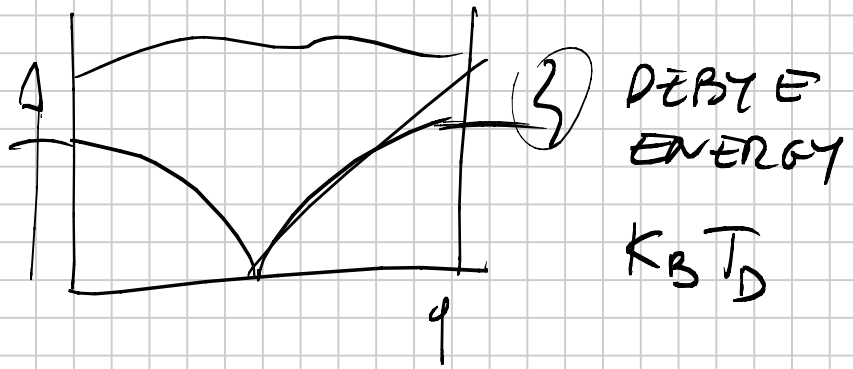
$$V_{ep}(q) \sim \frac{q}{\sqrt{\hbar\omega(q)}} \sim V_{ep}(q) \sim \sqrt{|q|}$$

$\hbar\omega(q) = \hbar v_s(q)$

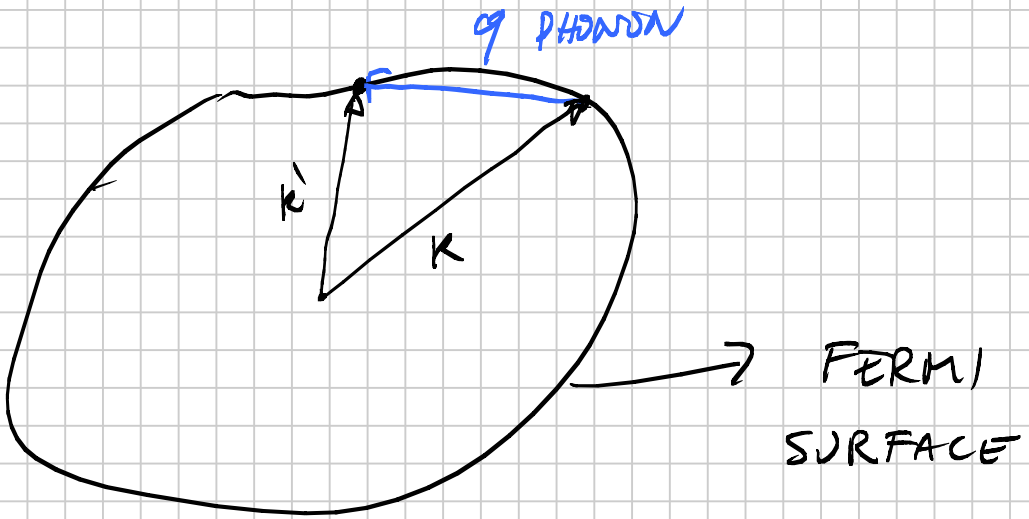
WHAT IS τ AVERAGE TIME BETWEEN

2 ELECTRON PHONON SCATTERING EVENTS

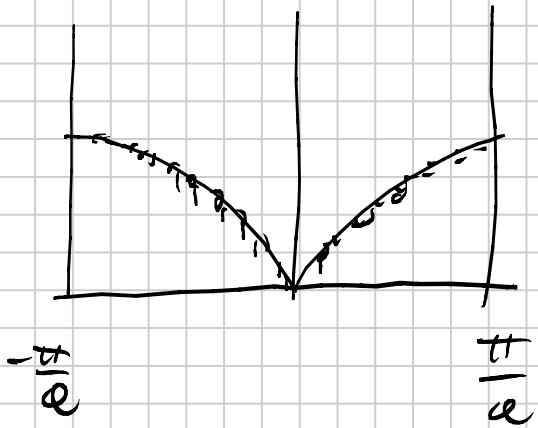
METALS



$T_D << T_F$



$T >> T_D$



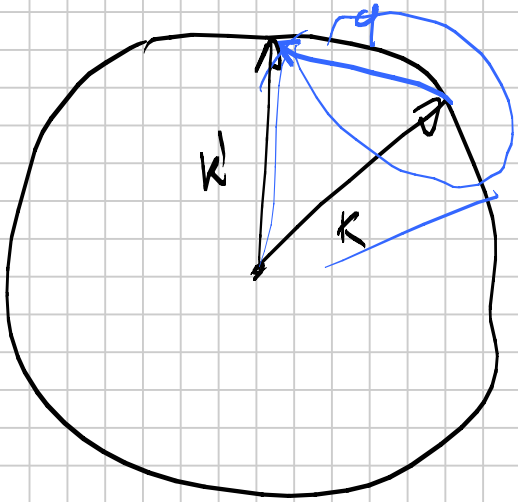
q OF PHONONS
CAN BE AS BIG
AS SIZE OF BZ

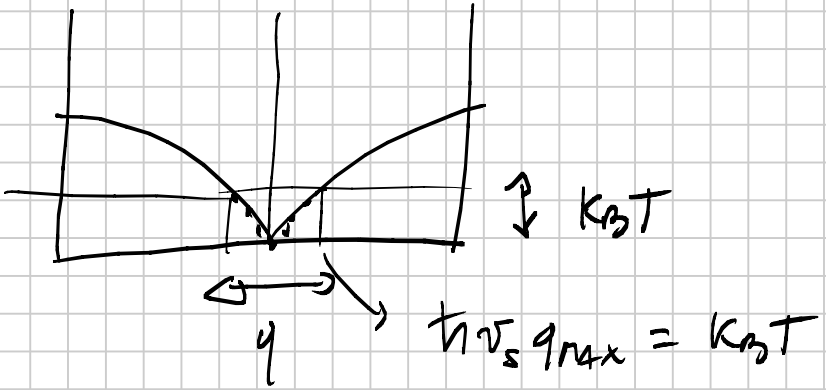
$\frac{1}{\tau}$ = RATE OF SCATTERING $\propto M(q_D)$

$$n(q_D) \sim \frac{1}{e^{\frac{\hbar\omega(q_D)}{k_B T}} - 1} \qquad T \gg T_D \qquad \sim \frac{k_B T}{k_B T_D}$$

$$\frac{1}{\tau} \propto T \quad \Rightarrow \quad \rho = \frac{1}{\sigma} \propto T$$

$T \ll T_D$





$\rightarrow$ ONLY A REGION OF

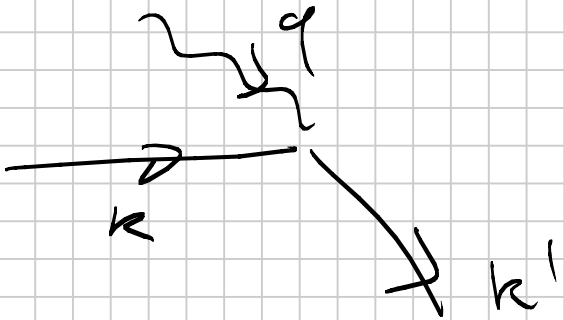
SIZE $\propto q_{MAX}^2 \Rightarrow \propto (k_B T)^2$

PHONON MODES ALLOWED IN THE SCATTERING

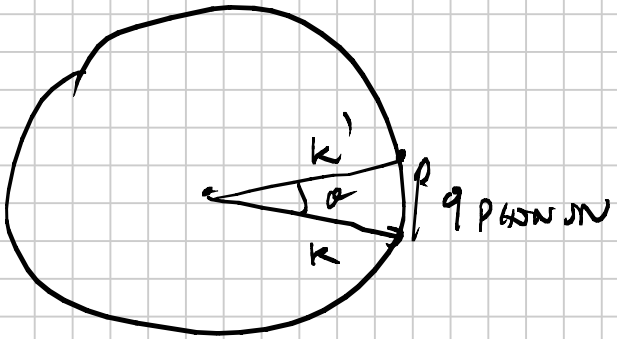
$$\rho \sim \frac{1}{\tau} \propto \boxed{|V_{ep}|^2 \propto |V_q|^2 \sim q \propto K_B T}$$

$$\rho \propto \underbrace{(\#\ \text{PHONON MODES})}_{T^2} \times \underbrace{|V_{ep}|^2}_{T} \propto \rho \propto T^3$$

GEOMETRICAL FACTOR



FORWARD SCATTERING



GEOMETRICAL FACTOR

$$F = (1 - \cos\theta)$$

FOR $T \ll T_D$

$$\rho(T) \propto \underbrace{\#\ \text{PHONON MODES}}_{T^2} \times \underbrace{|V_{ep}|^2}_{T} \times \underbrace{(1-\cos\theta)}_{T^2}$$

$$\cos\theta \sim 1 - \frac{\theta^2}{2} \Rightarrow F \sim \frac{\theta^2}{2}$$

$$\theta = \frac{q}{k_F}$$

$$\theta \sim \frac{q_{MAX}}{k_F}$$

$$(1-\cos\theta) \propto (k_B T)^2$$

BLOCH T^5 LAW