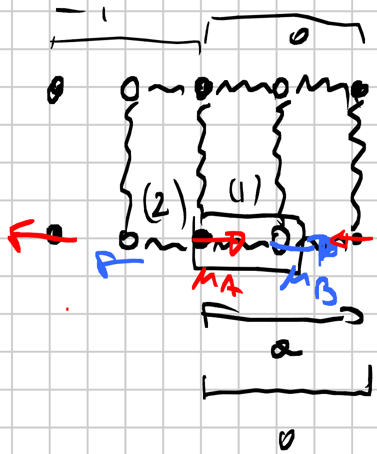
LECTURE #36

Note Title 4/16/2010

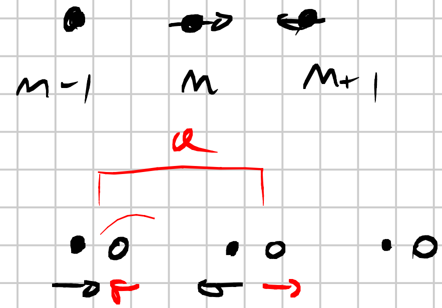


u_A

u_B

$\vec{q} = \left(\frac{\pi}{a}, 0\right)$

$q = \frac{\pi}{a}$



$e^{i\frac{\pi}{\cancel{a}} m \cancel{a}}$

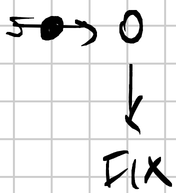
$$m_A \ddot{u}_A^0 = -K\underbrace{\left(u_A^0 - u_B^0\right)}_{\text{SPRING (1)}} - K\left(u_A^0 - u_B^{-1}\right) = -K\left(u_A^0 - \cancel{u_B^0}\right) - K\left(u_A^0 + \cancel{u_B^0}\right)$$

$$= 2K u_A^0$$

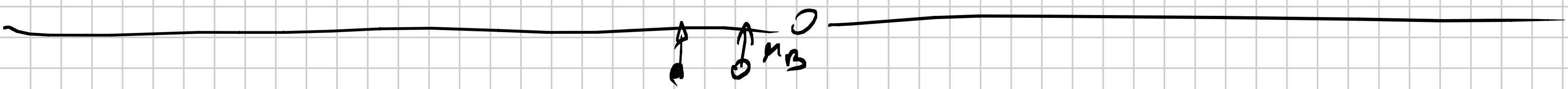
$$u_B^{-1} = -u_B^0$$

$$\omega_A^2 = \frac{2K}{m_A}$$

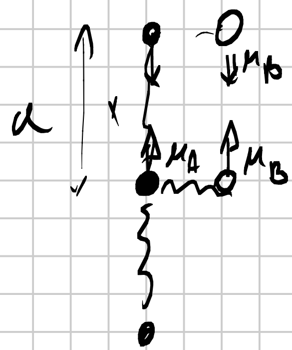
$$\omega_B^2 = \frac{2K}{m_B}$$



$$\omega_A = \sqrt{\frac{2k}{m_A}}$$



$$\vec{q} = \left(0, \frac{\pi}{a}\right)$$



$$O(\mu^2)$$

$$m_A \ddot{\mu}_A = -2k\mu_A - 2k\mu_A = -4k\mu_A$$

$$\omega_A^2 = \frac{4k}{m_A}$$

$$\omega_B^2 = \frac{4k}{m_B}$$

2D

$$E \propto \int_0^{k_D} dk \, k \, \frac{\hbar v k}{e^{\frac{\hbar v k}{k_B T}} - 1}$$

$$\frac{\hbar v k}{k_B T} = x$$

$$E \propto T^3 \int_0^{T_D/T \to \infty} \frac{x^2 \, dx}{e^x - 1}$$

$$E \propto T^3 \Rightarrow C_V \propto T^2$$

$$\lambda_s = \frac{1}{K_0}$$

$$K_0 = \frac{2\pi e^2}{\varepsilon_0} \boxed{\frac{\partial n}{\partial \mu}}$$

$2\pi k dk$

$$N = 2 \cdot \int \frac{d^2k}{\frac{(2\pi)^2}{A}} \, \vartheta\left(\mu - \frac{\hbar^2 k^2}{2m^*}\right)$$

$T = 0$

$$\varepsilon = \frac{\hbar^2 k^2}{2m^*} \qquad d\varepsilon = \frac{\hbar^2 k\, dk}{m^*}$$

$$\frac{N}{A} = n = \frac{1}{\pi}\int_0^\infty \frac{m^*}{\hbar^2}\,\theta(\mu-\varepsilon)\,d\varepsilon = \frac{m^*}{\hbar^2\pi}\mu$$

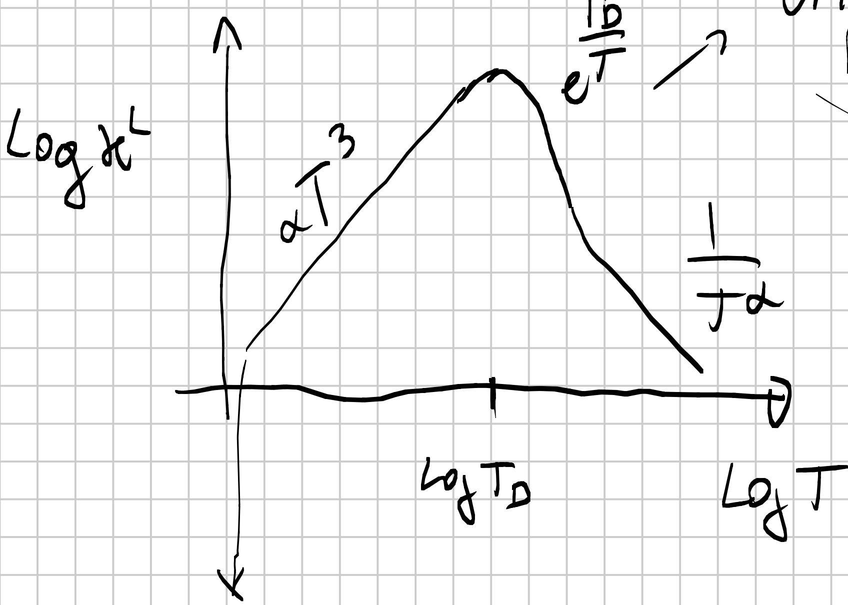
$$\frac{\partial n}{\partial \mu} = \frac{m^*}{\hbar^2\pi} \qquad k_0 = 2\cancel{\pi}\frac{e^2}{\varepsilon_0}\frac{m^*}{\cancel{\pi}\hbar^2}$$

$$k_0 = 2\,\frac{1}{\varepsilon_0}\left(\frac{m^*}{m_0}\right)\frac{e^2 m_0}{\hbar^2} = \frac{2}{\varepsilon_0}\,0.1\,\frac{1}{a_B}$$

$$\lambda_s \sim 25\,\text{Å}$$

THERMAL CONDUCTIVITY

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



UMKLAPP PROCESSESS $\rightarrow$ τ^P SHORTER

$\alpha \approx 1$

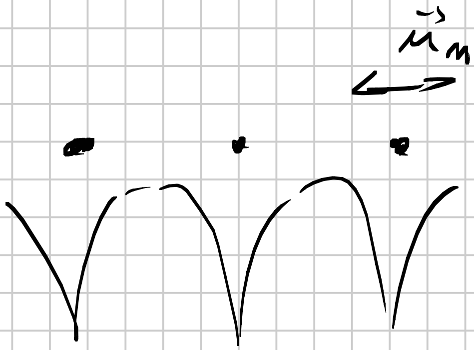
$\tau^P(T)$

$\tau^0 \cdot C_V$
$\downarrow$
T^3

ELECTRIC CONDUCTIVITY

$$\sigma = \frac{ne^2}{m} \tau^e$$

τ^e AVERAGE TIME BETWEEN 2 ELECTRON-PHONON SCATTERING



$$V^{IONS}(\vec{r}) = \sum_{R_m} V_{ATOMIC}(\vec{r} - \vec{R}_m)$$

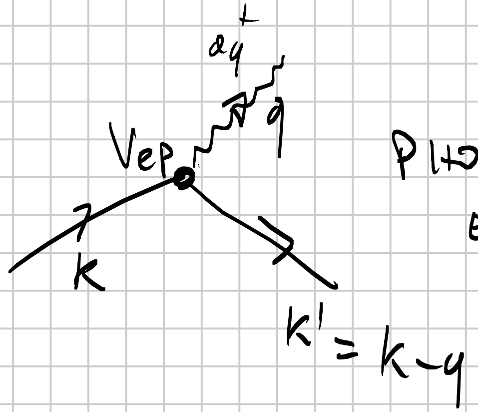
ACTUAL POTENTIAL

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

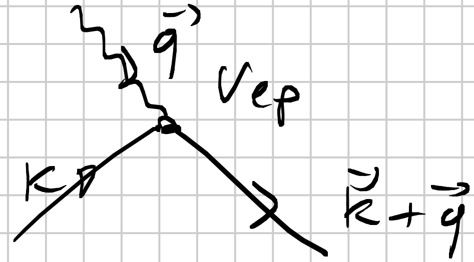
ELECTRON - PHONON INTERACTION

$$= \underbrace{\sum_{R_m} V_{AT}(\vec{r} - \vec{R}_m)} - \underbrace{\sum_{R_m} \vec{u}_m \cdot \vec{\nabla} V_{AT}(r - \vec{R}_m)}_{V_{ep}}$$

$$\vec{u}_m = \sum_q \frac{e^{iqR_m}}{\sqrt{2M\hbar\omega(q)}} (a_q^{+} + a_q)$$



PHONON EMISSION



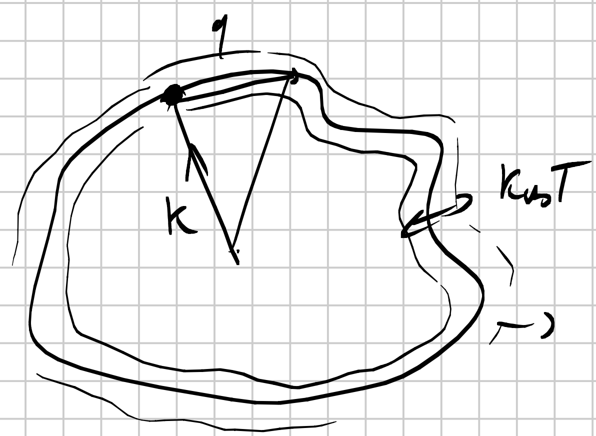
PHONON ABSORPTION

FROM ∇ $\qquad$ $\hbar\omega(q) \sim \hbar v_s q$

$$V_{ep} \sim \frac{1}{\sqrt{\hbar\omega(q)}} \times \vec{q} \Rightarrow \underline{\underline{V_{ep}}} \propto \sqrt{q}$$

HON $\qquad \tau(T)$ $\qquad\qquad T_D \ll T_F$

$T_F \gg T \gg T_D$

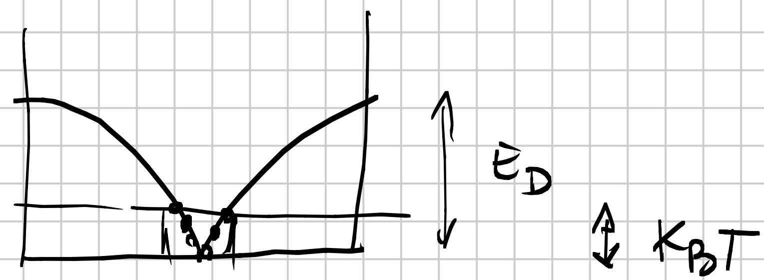


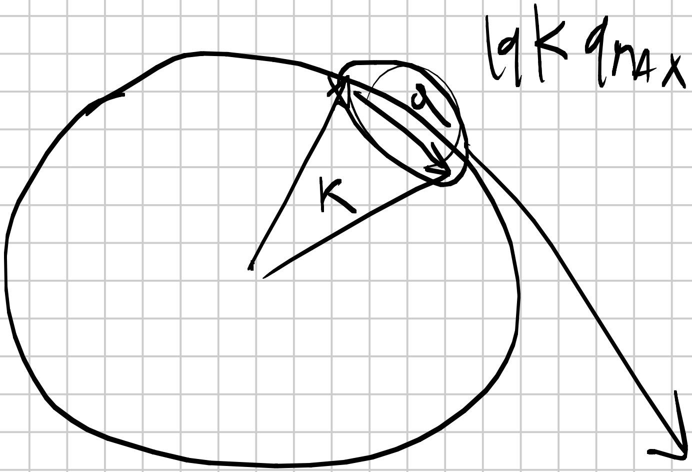
$\rightarrow$ FERMI SURFACE

SCATTERING RATE $\frac{1}{\tau} \propto$ TOTAL DENSITY OF PHONONS $\qquad n_{TOT} \propto T$

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

$T \ll T_D$





$q_{MAX} \Rightarrow \hbar v_s q_{MAX} = k_B T$

ONLY A REGION

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

RESISTIVITY $\rho \propto \frac{1}{\tau} = $ # PHONON MODES AVAILABLE FOR SCATTERING $\times \; |V_{ep}|^2$

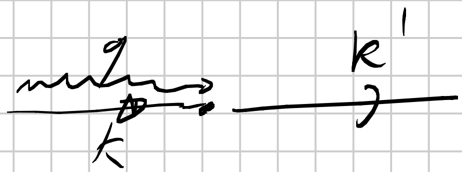
$V_{ep} \propto \sqrt{q}$

$(k_B T)^2$

$q \propto k_B T$

$\rho \sim T^3$

GEOMETRICAL FACTOR

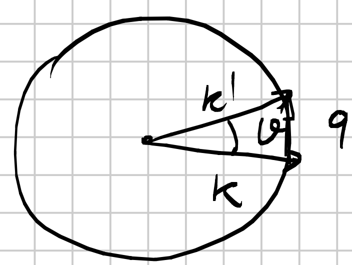


FORWARD SCATTERING

DOES NOT AFFECT

RESISTIVITY

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

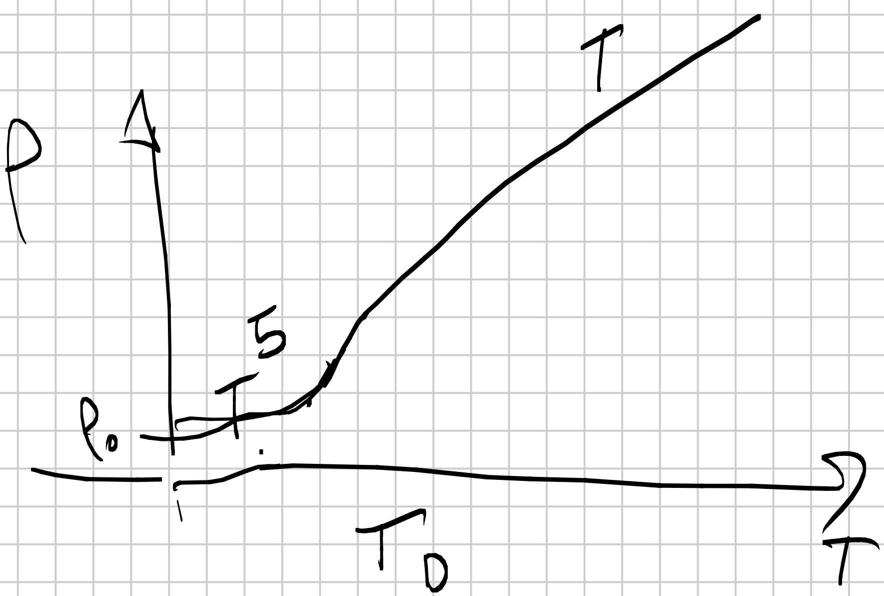


$\theta \sim \frac{q}{k_F}$

$$\frac{1}{\tau} \propto \overset{T^2}{\#\ \text{PHONON MODES}} \times \overset{T}{|V_{ep}|} \times \overset{T^2}{(1-\cos\theta)}$$

$$1-\cos\theta \sim \frac{\theta^2}{2} \sim \left(\frac{q_{MAX}}{K_F}\right)^2 \propto T^2$$

LOW T $\quad \rho \propto T^5 \quad$ BLOCH T^5 LAW RESISTIVITY



METALS