TRANSPORT PROPERTIES (NON-EQUILIBRIUM)

EXTERNAL FIELD, $\vec{E}$, $\vec{B}$, STRAIN, ΔT, "OPTICAL"
(TEMP. GRADIENT)

$$\vec{F} = -e\left(\vec{E} + \frac{\vec{v}}{c} \times \vec{B}\right)$$ (EXTERNAL FORCE)

$\vec{P}(t)$ HOW CHANGES IN TIME? (KINETIC THEORY)

t, $t + dt$

$\tau \approx$ "SCATTERING TIME" (PHENOMENOLOGICAL)

WORKS: F.D. STATISTICS (FERMIONS)
M.B. STATISTICS (CLASSICAL)

$$\left(1 - \frac{dt}{\tau}\right) \quad \text{DON'T SCATTER}$$

$$\frac{dt}{\tau} \quad \text{SCATTER}$$

$$\left(1 - \frac{dt}{\tau}\right)\left[\vec{P}(t) + \vec{F}\,dt + O(dt^2)\right] \quad \text{DON'T SCATTER}$$

$$\frac{dt}{\tau}\left[0 + \vec{F}(t)\,dt + O(dt^2)\right] \quad \text{SCATTER}$$

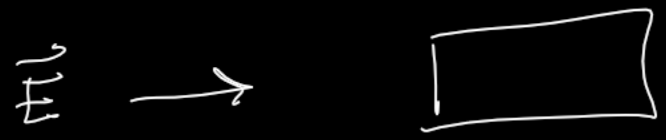
$$\vec{P}(t+dt) = \left(1 - \frac{dt}{\tau}\right)\left[\vec{P}(t) + \vec{F}(t)\,dt\right] + O(dt^2)$$

$$\vec{p}(t+dt) - p(t) = dt\left(-\frac{\vec{p}(t)}{\tau} + \vec{F}(t)\right)$$

$$\boxed{\frac{d\vec{p}}{dt} = -\frac{\vec{p}}{\tau} + \vec{F}}$$

VISCOUS DRAG TERM

CONDUCTIVITY OF FREE ELECTRON GAS



$$\vec{F} = -e\vec{E}$$

$\vec{j}$ (CURRENT DENSITY) $= n(-e)\vec{v}$ $\qquad \vec{j}\cdot\vec{A} = I$

$$\vec{v} = \frac{\vec{p}}{m} \Rightarrow \frac{d\vec{v}}{dt} = -\frac{\vec{v}}{\tau} + \frac{\vec{F}}{m} \Rightarrow \frac{d\vec{v}}{dt} + \frac{\vec{v}}{\tau} = -\frac{e\vec{E}}{m}$$

STEADY STATE $\frac{d\vec{v}}{dt} = 0$

$$\Rightarrow \vec{v} = -\frac{eE\tau}{m} \Rightarrow \boxed{\vec{j} = \frac{ne^2\tau}{m}\vec{E}}$$

σ = CONDUCTIVITY $\qquad \vec{j} = \sigma\vec{E}$ $\qquad \boxed{\sigma = \frac{ne^2\tau}{m}}$ DRUDE CONDUCTIVITY

(D.C. CONDUCTIVITY)

A.C. CONDUCTIVITY

$\vec{E}_0 e^{i\omega t}$

$$\vec{v} = \vec{v}_0 e^{i\omega t} \qquad \frac{d\vec{v}}{dt} = i\omega \vec{v}_0 e^{i\omega t}$$

$$i\omega \vec{v}_0 \cancel{e^{i\omega t}} + \frac{\vec{v}_0}{\tau} \cancel{e^{i\omega t}} = -\frac{e\vec{E}_0}{m} \cancel{e^{i\omega t}}$$

$$\vec{v}_0 = \frac{-e\vec{E}_0}{m(i\omega + 1/\tau)} \Rightarrow \boxed{\sigma(\omega) = \frac{ne^2\tau}{m(1+i\omega\tau)}}$$

AC CONDUCTIVITY

$$\sigma(\omega) = \frac{\sigma_0}{1 + i\omega\tau}$$

$\sigma_0 \to$ DC

$\rho \quad \left(\equiv \frac{1}{\sigma} \right)$

RESISTIVITY

$$\boxed{\mu\Omega\text{-cm}}$$

<u>UNITS</u> ρ

$10^{-6}\,\Omega$-cm

<u>METALS</u>

(TABLE 3 IN BOOK)

τ LATTICE VIBRATIONS (PHONONS)

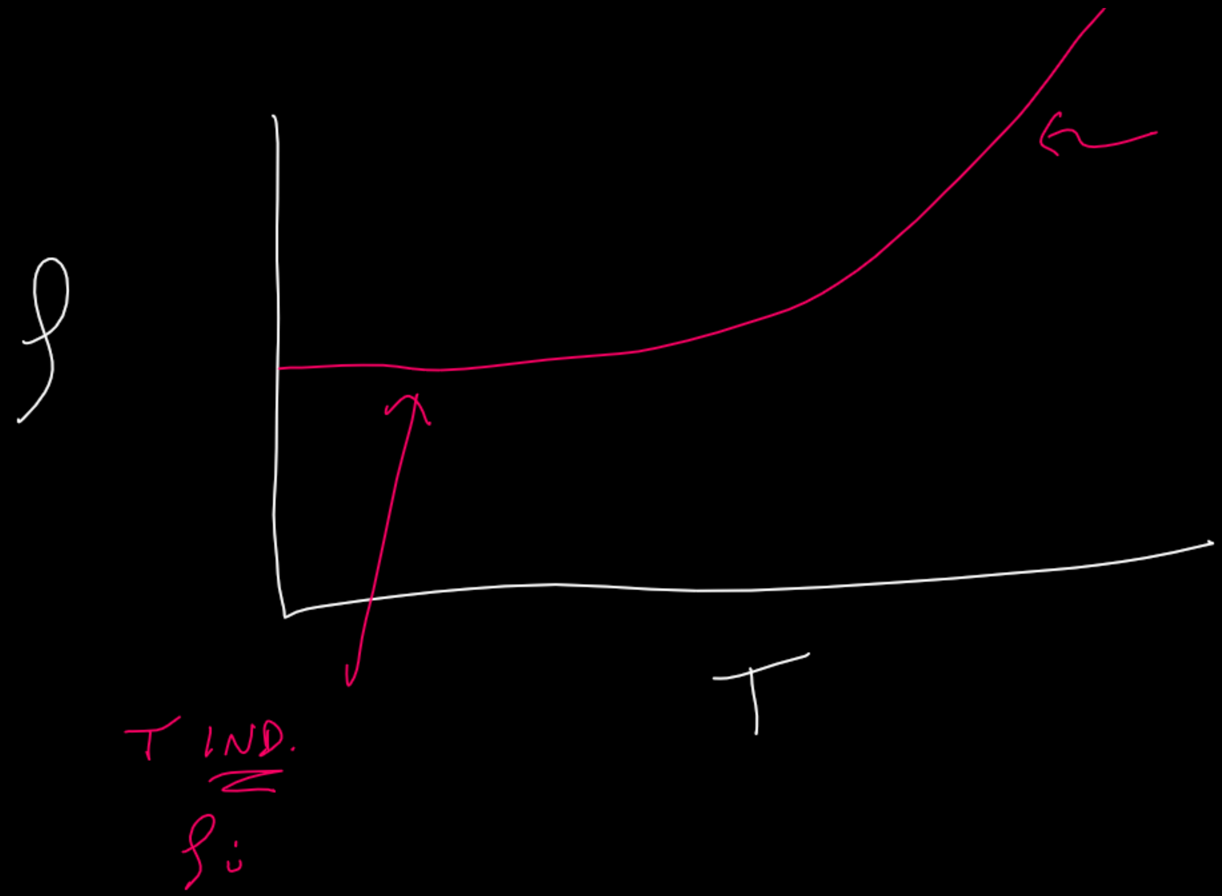
IMPURITIES

$$\frac{1}{\tau} = \frac{1}{\tau_i} + \frac{1}{\tau_L} \Longrightarrow \rho = \rho_i + \rho_L$$

τ_i: IMPURITY

τ_L: LATTICE

"MATTHIESSEN'S RULE"



R.R.R (RESIDUAL RESISTIVITY RATIO)

$$RRR \equiv \frac{\rho(300\,K)}{\rho(0\,K)}$$

RRR $\Longleftrightarrow$ PURITY

MOTION IN A MAGNETIC FIELD

$$\vec{F} = -e\left(\vec{E} + \frac{\vec{v}}{c} \times \vec{B}\right)$$

$$\frac{d\bar{v}}{dt} + \frac{\bar{v}}{\tau} = -\frac{e}{m}\left(\vec{E} + \frac{v}{c}\times\vec{B}\right)$$

D.C. CASE $\frac{d\vec{v}}{dt} = 0$

PICK $\vec{B} = B\hat{z}$

$$\vec{v}\times\vec{B} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ v_x & v_y & v_z \\ 0 & 0 & B \end{vmatrix} = v_y B\hat{x} - v_x B\hat{y}$$

$$\frac{v_x}{\tau} = -\frac{e}{m}\left(E_x + \frac{B}{c}v_y\right)$$

$$\frac{v_y}{\tau} = -\frac{e}{m}\left(E_y - \frac{B}{c}v_x\right)$$

$$\frac{v_z}{\tau} = -\frac{e}{m}E_z$$

$\omega_c \equiv \frac{eB}{mc}$ "CYCLOTRON FREQUENCY"

$\frac{eB}{mc}\tau$ DIMENSIONLESS

$\omega\,(10^9\ Hz) = 17.6 \times H\ (KILOGAUSS)$

EARTH'S $B \sim 0.5$ GAUSS

1 TESLA = 10,000 GAUSS

LABS @ UF

$\sim$ 9 T

$\sim$ 20T μKELVIN LAB

↳ SUPERCONDUCTING

35 T MAGNET @ NHMFL
(DC)

PULSED MAGNETICS $\sim$ 150 T

FLUX COMPRESSION $\sim$ 500 T (SAMPLE DESTROYED)

EXPLOSIONS $\sim$ 1000T