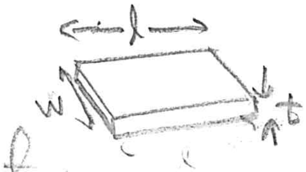
Results from Drude Model so far



1) $\sigma = \dfrac{ne^2\tau}{m}$ $\tau \rightarrow$ Relaxation time

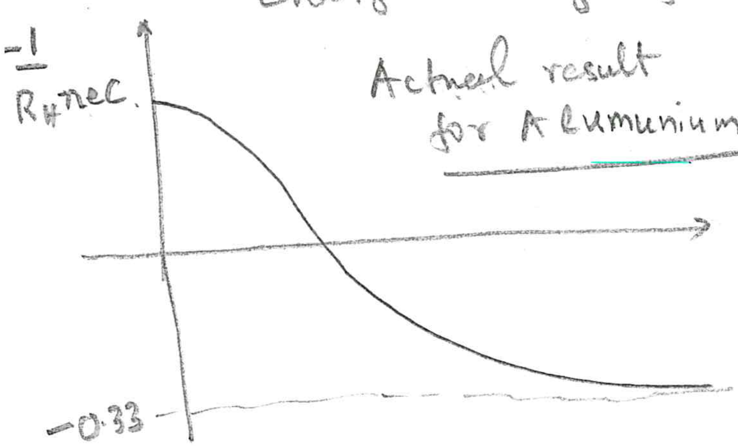
2) $R_H = -\dfrac{1}{n|e|c}$ $R_H \rightarrow \dfrac{E_y}{J_x B}$, the Hall coefficient.

Experimentally, R_H is a measurable quantity $R_H = \dfrac{V_H}{W \frac{I}{wt} H} = \dfrac{V_H t}{H}$

Contrary to $R_H = -\dfrac{1}{nec}$ which is a constant, independent of B, R_H does show significant field dependence for many elements. (See page 15, Ashcroft Mermin) and also can imply a +ve charge at high fields.

$-\dfrac{1}{R_H nec} = 1$ from Drude's model.

Actual result for Alumunium



$\omega_c \tau \rightarrow \dfrac{eB\tau}{mc}$, dimensionless

Metal	Valence	$-1/R_H nec$ at moderate to high fields and low T
Li	1	0.8
K	1	1.1
	1	
Rb	1	1.0
Ca	2	1.5
Be	2	-0.2
Al	3	-0.3
In	3	-0.3
Mg	2	-0.4

0.8, 1.1, 1.0 $\rightarrow$ Reasonable agreement

1.5, -0.2, -0.3, -0.3, -0.4 $\rightarrow$ Large deviations both in magnitude and sign

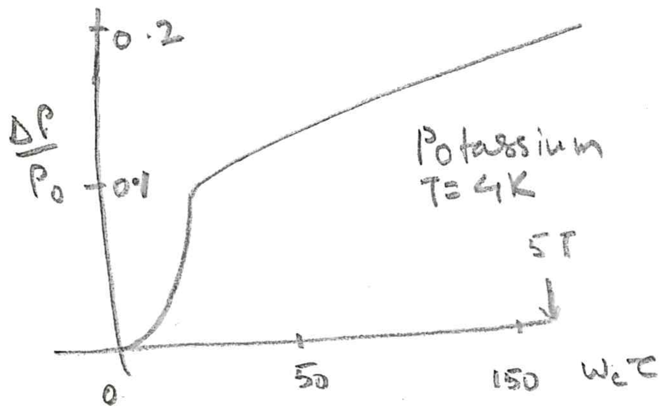
Alkali metals show reasonable agreement with Drude's model.

Resistance and magnetoresistance → $\frac{\rho(B)-\rho_0}{\rho_0} = \frac{\Delta\rho}{\rho_0}$

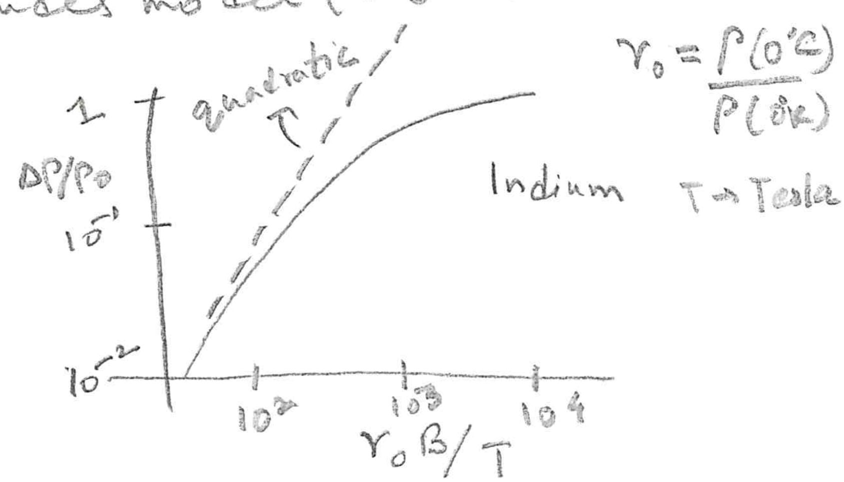
Just like the Hall-coefficient resistivity under B can show large changes, contrary to Drude model which shows that $J_x = \sigma_0 E_x$ even in the presence of B.

⇒ Drude model implies zero magenoresistance (MR)

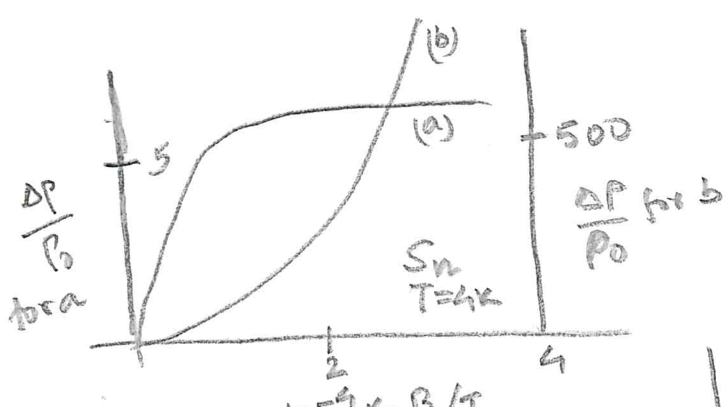
Again, almost all metals show ~~magneto~~ MR of varying magnitude. Alkali metals typically show small MR, which somewhat comes closest to Drude's model (e.g. K)



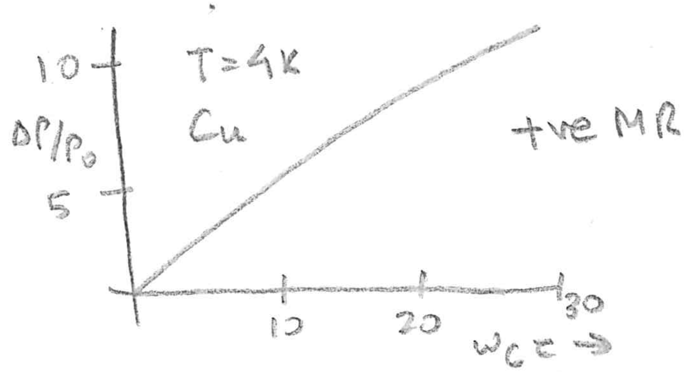
low MR, quadratic at low B, linear at high $\omega_c\tau$

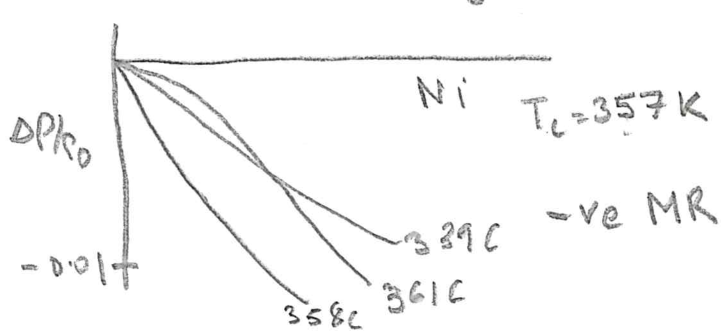


High MR, quadratic at low B



Quadratic dependence when B is along (b). MR saturates when B along (a) with an extremely small quadratic range





Magnetoresitance of pure metals

$$MR = \frac{\Delta\rho}{\rho(0)} \quad \text{or} \quad \frac{\Delta\rho}{\rho_0} = \frac{\rho(B) - \rho(0)}{\rho(0)}$$

ρ is in general a tensor. We are concerned with the diagonal elements ρ_{xx} or ρ_{yy} → For isotropic materials

$\rho_{xx} = \rho_{yy} = \rho_{zz}$ at $B = 0$.

$$MR = \frac{\rho_{xx}(B) - \rho_0}{\rho_0}$$

Off diagonal components are related to Hall resistivity.

$$\rho_0 = 1/\sigma_0 = \frac{m^*}{ne^2\tau} \overset{OR}{\Rightarrow} \tau = \frac{\sigma_0 m^*}{ne^2}$$

Since ρ_0 is reduced at low T, MR is much higher at low temperatures and and high magnetic fields.

MR for Cu at RT = 2% at 10 T

" " " at low T = 14 times higher at 10 T.

MR of Bismuth at low T = 10^6 at 10 T.

τ → time between collisons.

OR time ~~befor~~ afterwhich current dies away after field has been removed

OR $1/\tau$ = collision-probability ;

Magnetic field will have a strong effect if it can bend the trajectory during free path.

$v \times B$ force bends the path into helics whose angular frequency $\omega_c = eB/m^*$

Mean angle turned between collisions is $\omega_c \tau$ and unless $\omega_c \tau > 1$ no great magnetoresistance is expected (though it does not guarantee MR)

$$\omega_c \tau = \frac{eB}{m}\left(\frac{\sigma_0 m^*}{ne^2}\right) = \frac{B\sigma_0}{ne}$$

For copper $n = 8.5 \times 10^{28}\ m^{-3}$

At $0°C$ $\sigma_0 = 6.4 \times 10^7\ \Omega^{-1} m^{-1}$ (depends on sample)

$\Rightarrow \omega_c \tau = 4.7 \times 10^{-3}\ B$

even at $B = 30T$ $\omega_c \tau \approx 0.14 \Rightarrow$ Small effect expected

At $4K$, $\sigma_0 = 606 \times 6.4 \times 10^7\ \Omega^{-1} m^{-1}$

at $B = 10T$ $\omega_c \tau = 28 \Rightarrow \approx 4 \times 2\pi$

electrons make 4 complete turns between collision $\rightarrow$ should show appreciable magnetoconductivity.

The case of Bismuth deserve special mention as it shows a MR of $>10^6$ at 10T at 4.2 K.

1) Kaptiza measured is first in 1928. (2) Alers and Webber PR 91 (1953)

Bismuth also shows no apparent saturation effects.

It also shows oscillatory behavior in transport at high magnetic field $\rightarrow$ Subhnikov-de Hass oscillations