Concepts in Mesoscopic Physics

Drude Conductivity

$$\sigma = en\mu = \frac{ne^2 \tau_m}{m^*}$$

rewrite using $k_F = \sqrt{2\pi n}$

$$\ell = v_F \tau_m$$

$$v_F = \frac{\hbar k_F}{m^*}$$

$$\sigma = g_s g_v \frac{e^2}{h} \frac{k_F \ell}{2} = \frac{2e^2}{h} \frac{k_F \ell}{2}$$

rewrite using

$$\rho_{DOS} = \frac{g_s g_v m^*}{2\pi\hbar^2} = \frac{m^*}{\pi\hbar^2}$$

$$D = \frac{1}{2} v_F^2 \tau_m = \frac{1}{2} v_F \ell$$

$$\sigma = e^2 \rho_{DOS}(E) D$$

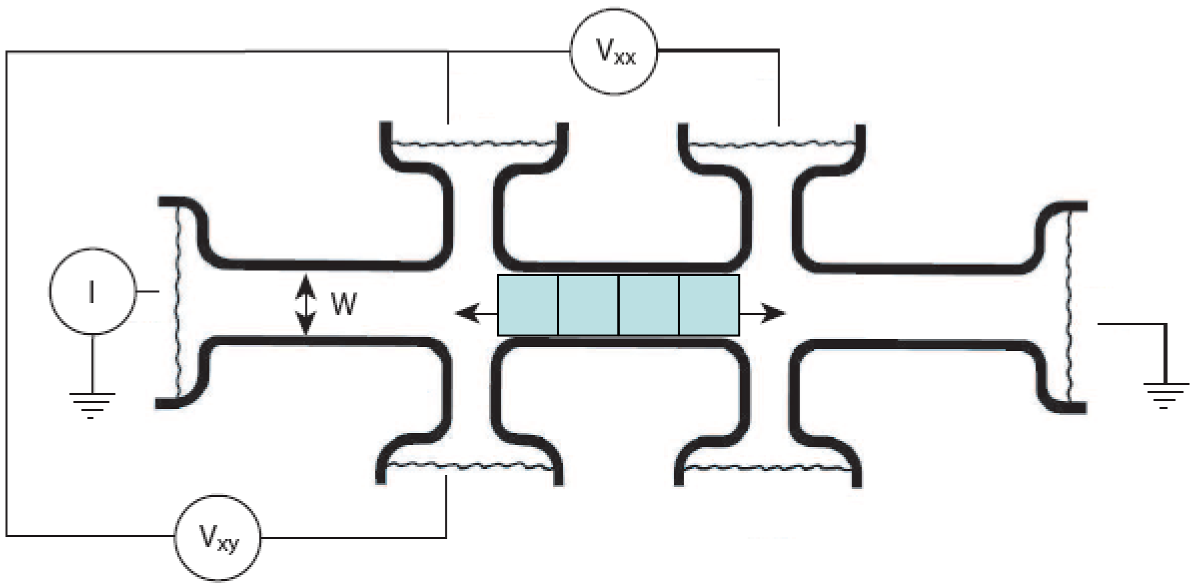
Resistance per Square

2D: resistivity and resistance: same units

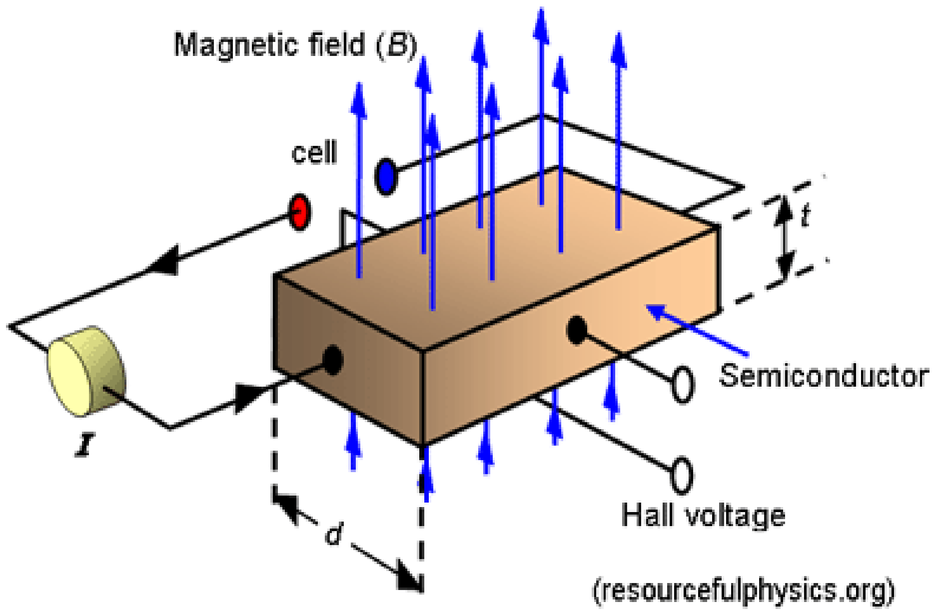
$$R = \rho \frac{L}{W} = \rho_{\square} \frac{L}{W}$$

$\rho_{\square}$ resistance per square

example: Hall bar

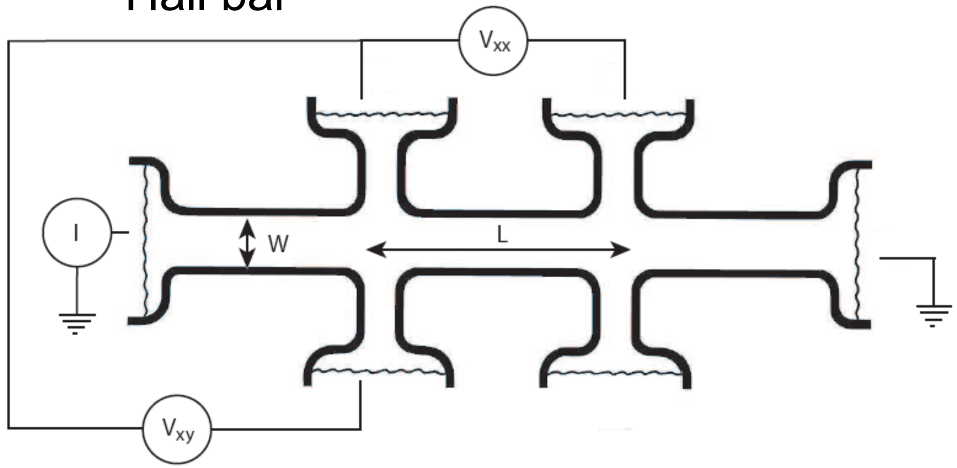


Classical Hall Effect



2D: thickness t drops out

Hall bar

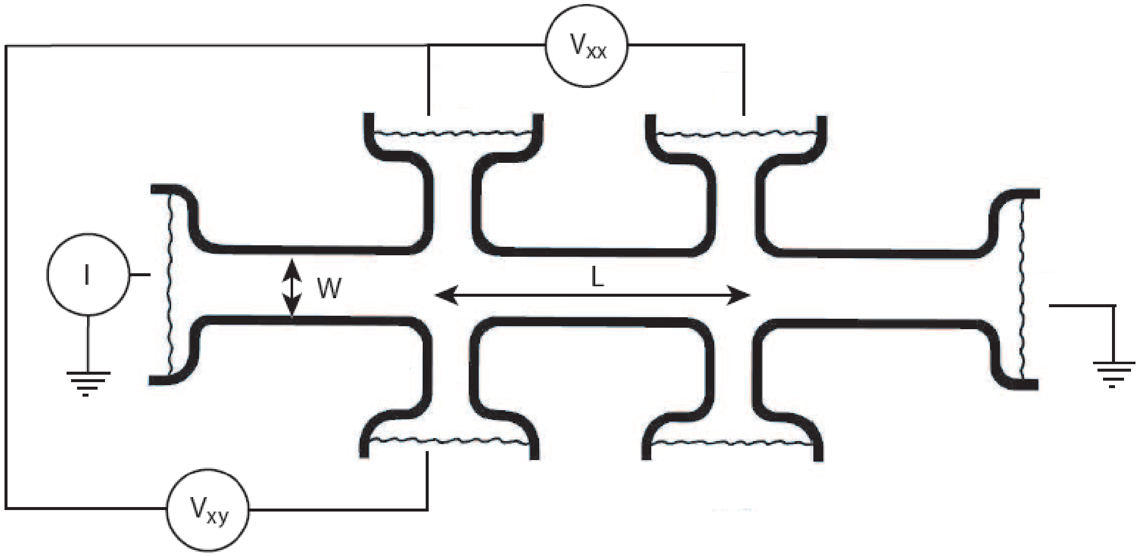


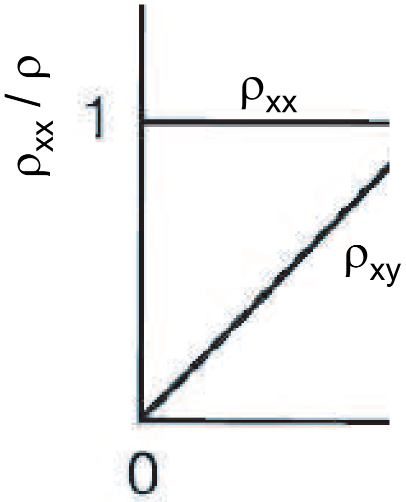
$$\frac{m^* v_d}{\tau_m} = e\left[E + v_d \wedge B\right]$$

$$\begin{pmatrix} \frac{m^*}{e\tau_m} & -B \\ +B & \frac{m^*}{e\tau_m} \end{pmatrix} \begin{pmatrix} v_x \\ v_y \end{pmatrix} = \begin{pmatrix} E_x \\ E_y \end{pmatrix}$$

$$\rho_{xx} = \sigma^{-1}, \quad \rho_{xy} = -\rho_{yx} = -\frac{B}{en}$$

Classical Hall Effect





$$V_x = R_{xx} I_x \qquad R_{xx} = \frac{L}{W}\rho_{xx}$$

$$V_H = V_y = \rho_{yx} I_x = \frac{B}{en} I_x = R_H I_x$$

$$R_H = B/(en)$$

$$R_H \sim 3.1\,\mathrm{k}\Omega/\mathrm{Tesla} \text{ for } n \sim 2 \times 10^{-11}\,\mathrm{cm}^{-2}$$

$$\mu = (n e R_{xx} W/L)^{-1}$$