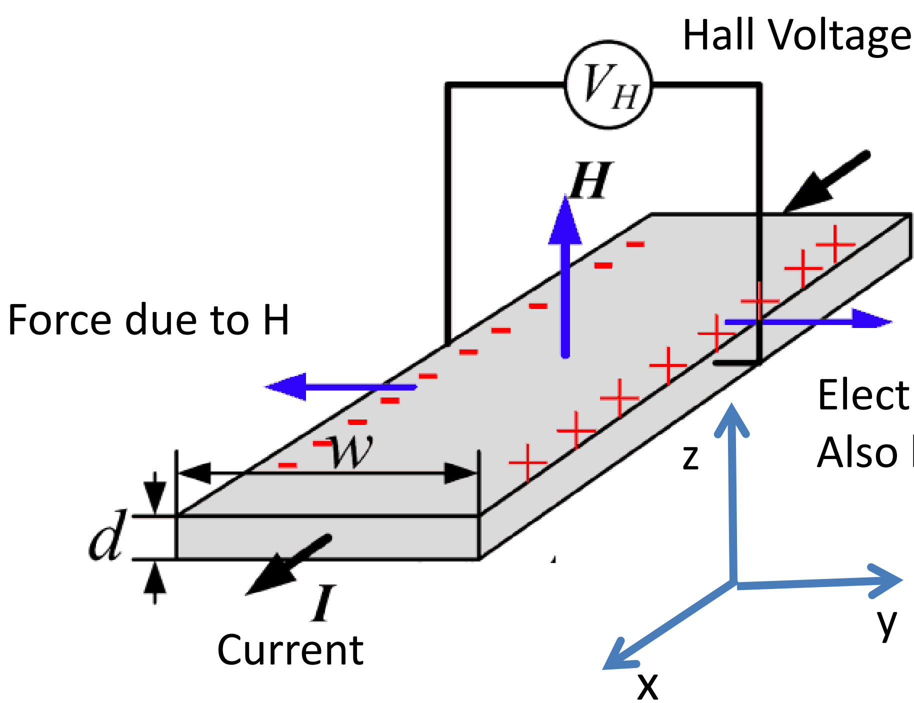
Classical Hall Effect (Edwin Hall-1879)

Standard Geometry for the Hall-effect:

Transverse electric field (Hall-Field) just cancelled the Lorentz force due to magnetic field



$$R_H = \frac{E_y}{j_x B}$$

$$R_H = -\frac{eB\tau E_x/mc}{ne^2\tau E_x B/m} = -\frac{1}{nec} \quad \text{(CGS)}$$

$$R_H = -\frac{1}{ne}\,. \quad \text{(SI)}$$

Classical Hall Effect

<u>Two resistivity components:</u>

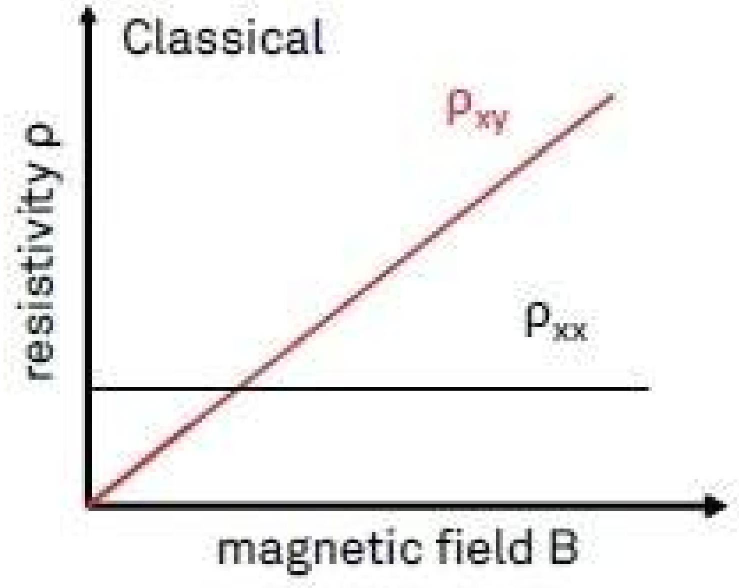
ρ_{xx}: Longitudinal resistivity (Magneto-resistance)

ρ_{xy}: Transverse resistivity (Hall resistance)

Resistivity is the property of material and is independent of shape and size. Resistance is related to resistivity as

For 3D: $R = \rho\ (L/A) = \rho L^{2-D}$

General: Variation of longitudinal and transverse resistivity's as a function of magnetic field.



$\rho_{xx} = 1/(ne\mu)$ = constant

$\rho_{xy} = B/(ne)$ = proportional to B

Quantum Hall Effect (QHE) (K. von Klitzing-1980)

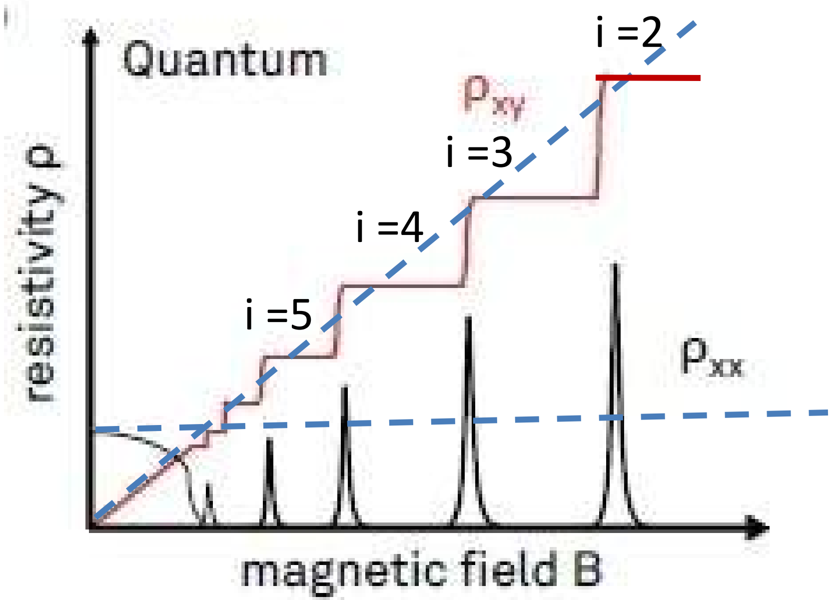
- Low dimensions: 2D (Thin film-restricting third z-dimension)
- High Magnetic field (Tesla)
- Low temperature

The striking feature of the quantum Hall effect is the persistence of the quantization

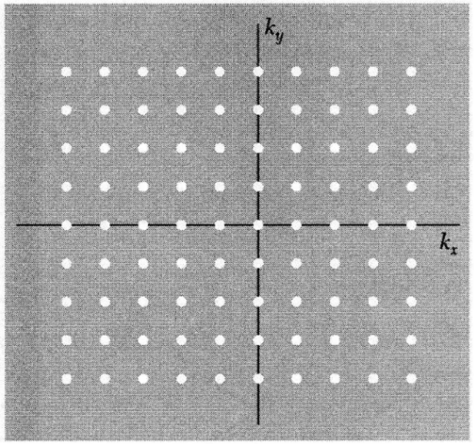
ρ_{xy}:are in units of h/e^2 and are universal i.e. independent of materials.

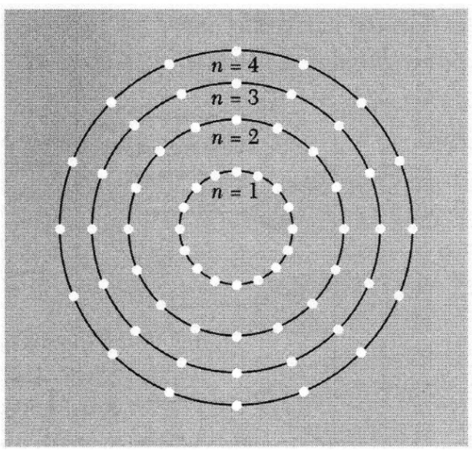
ρ_{xx}: Zero most of the time but shows peak when shows transition from one plateau to another. It is going under a transition from metal to insulator.

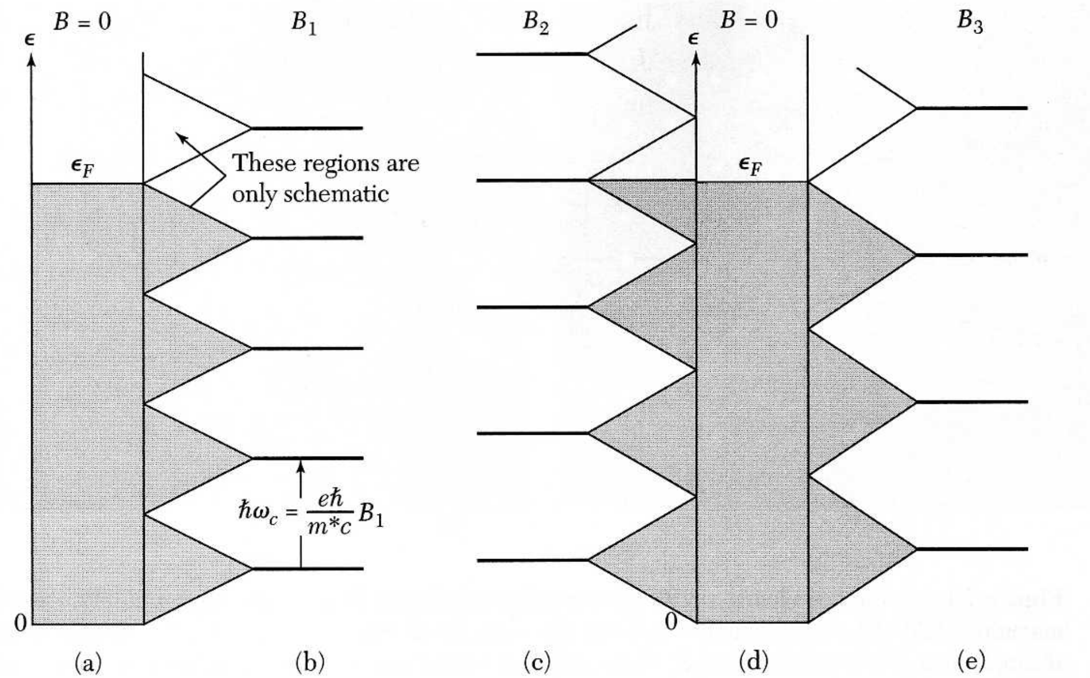
$\rho_{xy} = (h/e^2)(1/\gamma)$ where γ is an integer



Landau magnetic sub-bands







Effect of magnetic field on the Fermi-energy levels of 2 dimension electron gas. (a) and (d) the states in the absence of magnetic field. Each circle corresponds a energy levels states with qunatum number n having energy $(n+1/2)\ \hbar\omega$. The area between the two successive circles $= \pi\Delta(k^2) = (2\pi m/\hbar^2)\Delta E = 2\pi\ eB/\hbar c$.

The number of orbital in one magnetic sub-band = $(2\pi\ eB/\hbar c)(L/2\ \pi)^2$. (spin ignored)

Quantum Hall Effect (QHE) (K. von Klitzing-1980)

From the expression of Landau magnetic sub-bands:

Number of orbital's (degeneracy) in one Landau level is given by $D = (eB/hc).L^2$ (Refer to your notes)

where L is dimension of the sample. So, the number of states per unit area in the Landau levels is given by

$N/L^2 = eB/hc = N_0$ (say the degeneracy of Landau level per unit area)

Consider the situation when j Landau levels are completely filled then the number of electrons per unit area can be written as jN_0.

Hall resistance is given by

$R_H = B/Nec$ (from slide 1, CGS) $= B/[(eB/hc)jec] = Bhc/e^2Bjc = (h/e^2)(1/j)$

Where j is integer. This is quantum hall resistance.

Fermi-Surface construction

Using the concept of quantization of electron orbit in magnetic field

$$S(1/B_{n+1} - 1/B_n) = 2\pi e/\hbar c$$

Equal increments in 1/B produce similar orbits. The periodicity in 1/B is a striking feature of magneto oscillatory effect in metals at low temperatures: resistivity, susceptibility, heat capacity.