Notes:

- Homework 7: due today (I will hand out solutions this week)
- No class on Wednesday this week (I will be in office hrs.)
- Exam: Friday 1PM, location MPHY 213.

Same format as before, open Ashcroft & Mermin text.

Chapters:
12 (effective mass, E & B field semiclasscal)
14 (transport in metals)
17 (Hartree fock, Landau theory)
21-26 (vibrations & phonons, also transport)
28-29 semiconductor physics.

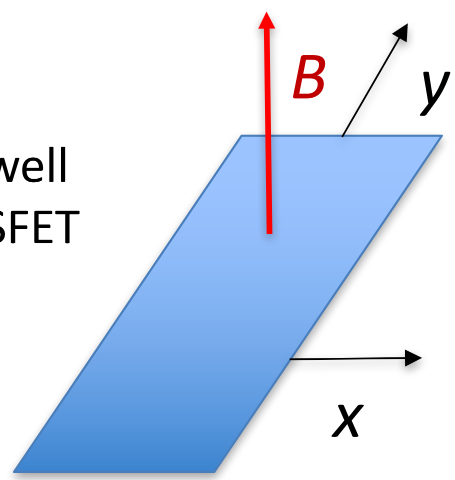
2D Quantized states in magnetic field

Neglect *V* here, & assume *m* is isotropic effective mass (GaAs case).

$$\mathcal{H} = \frac{1}{2m}\left(\hbar\vec{k} + \frac{e\vec{A}}{c}\right)^2 + \cancel{eV}$$

$$\vec{A} = (\tfrac{1}{2}r \times B) \text{ or } (-\hat{y}xB_z)$$

2DEG layer:
e.g. 1D square well in z-dir., or MOSFET confined states



2DSHO "circulating" solutions.

1DSHO "traveling" solutions

Landau orbitals, levels E_n:
Large # degenerate solns., degeneracy $B\times(\text{Area})/\Phi_o$ per Landau Level.

More general $k \rightarrow i\nabla$

$$\mathcal{H} = \frac{1}{2m}(\hbar k_x)^2 + \frac{1}{2m}\left(\hbar k_y - \frac{exB}{c}\right)^2 \Rightarrow$$

$$\psi = e^{ik_y y}X(x - x_o)$$

$$E_n = (n + \tfrac{1}{2})\hbar\omega_c$$

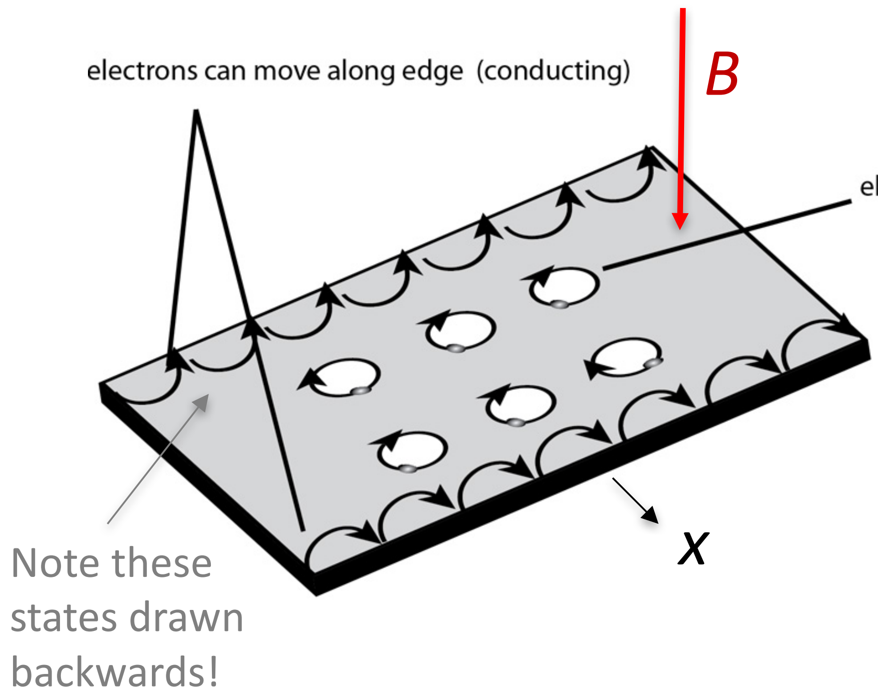
"traveling" solns

cyclotron
$$\omega_c = \frac{eB}{mc}$$

Quantum Hall effect & related phenomena (2DEG):

$$\mathcal{H} = \frac{1}{2m}\left(\hbar\vec{k} + \frac{e\vec{A}}{c}\right)^2 + eV$$

$$\vec{A} = (\tfrac{1}{2}r \times B) \text{ or } (-\hat{y}xB_z)$$



Circulating & traveling solutions equivalent; degeneracy $B\times(\text{Area})/\phi_o$ per Landau Level lifted by slow change in potential.

$$E_n = (n + \tfrac{1}{2})\hbar\omega_c$$

n^{th} Landau level
good for relatively small fields.

$$\Phi_o = \frac{hc}{e} \approx 4\times10^{-12}\ \text{G·cm}^2 \text{ or } 4\times10^{-15}\ \text{T·m}^2$$

Non-superconducting flux quantum

Quantum Hall effect & related phenomena (2DEG):

chapter 1
Hall effect:

$$\frac{1}{nec} = \frac{E_x}{j_y B}$$

2D version:

$$\rho_{xy} = \frac{V_x}{I_y} = \frac{B}{nec}\frac{1}{t} \Rightarrow \frac{h}{me^2}$$

m = # of filled Landau Levels

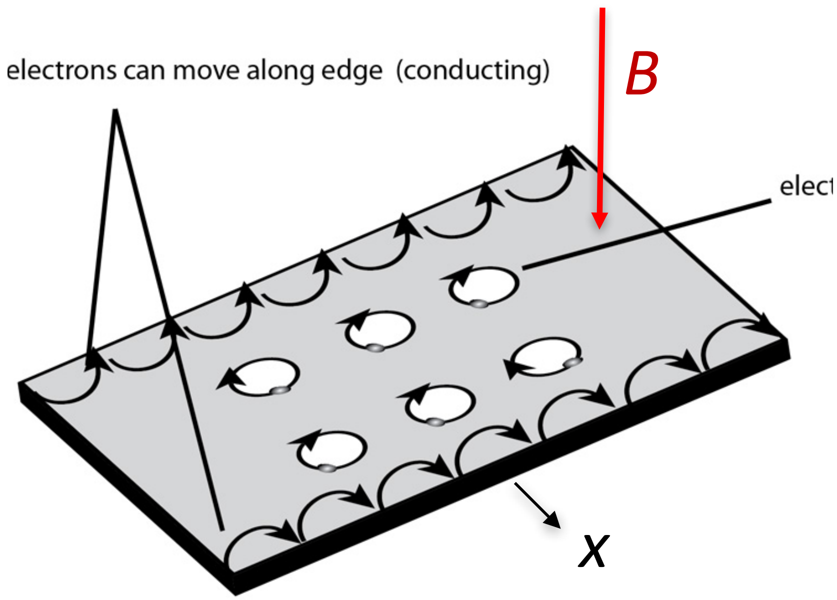
Landau level filling:

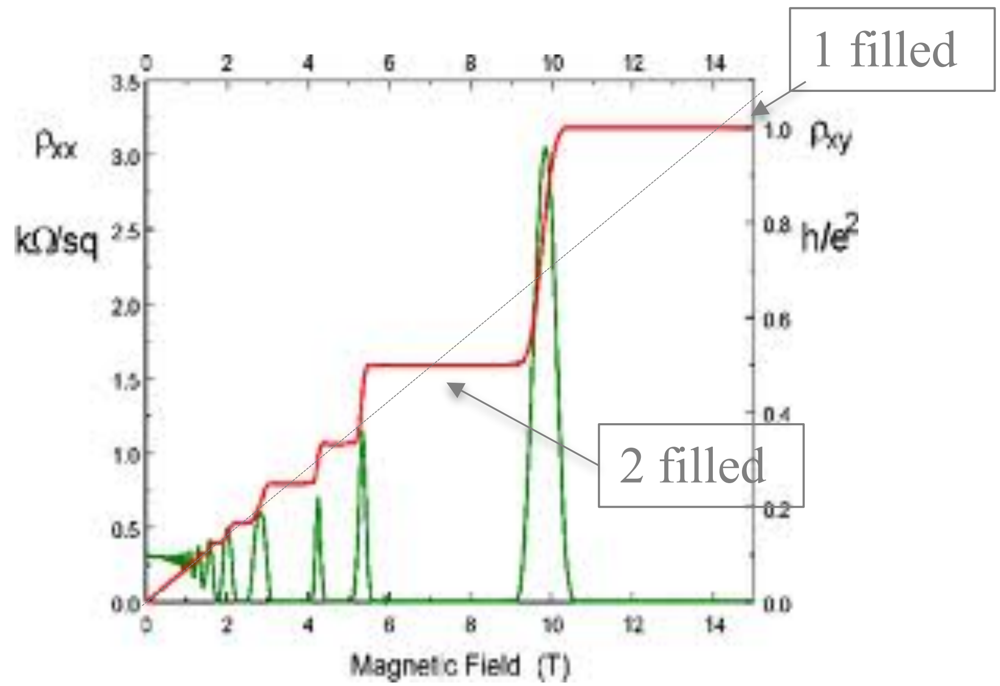
$$N_o = \frac{BA}{\Phi_o}$$

N_o = # of electrons/L.L.

$$\Phi_o = \frac{hc}{e}$$

3D vs 2D: A = sample area; 3D carrier density is $n = mN_o/(At)$, with t = thickness





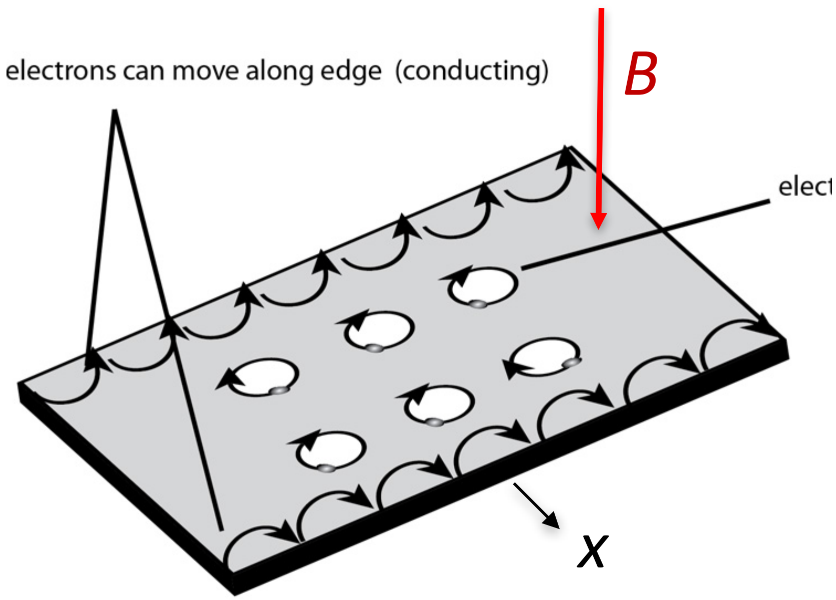
Quantum Hall effect & related phenomena (2DEG):

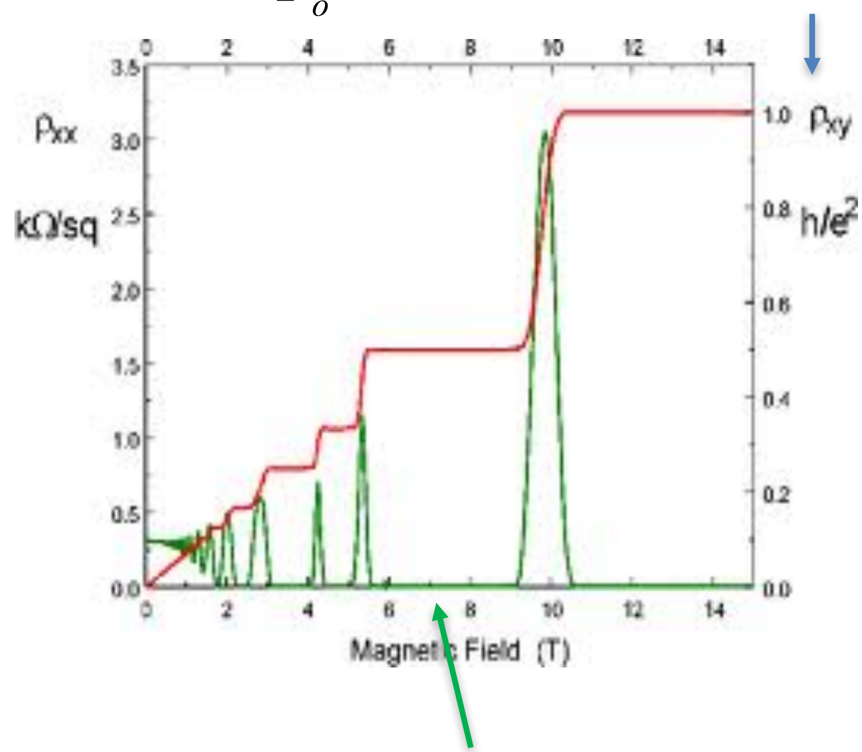
$$\rho_{xy} = \frac{V_x}{I_y} = \frac{B}{nec}\frac{1}{t} \Rightarrow \frac{h}{me^2}$$

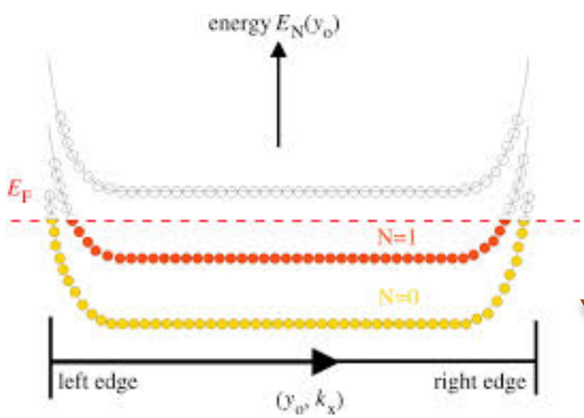
$$\Phi_o = \frac{hc}{e}$$

$$N_o = \frac{BA}{\Phi_o}$$

$h/e^2 \approx 25813\ \Omega$ quantum of resistance







Zero resistance with filled Landau levels!

back-scattering prohibited, currents separate

Edges & center disorder lift degeneracy.