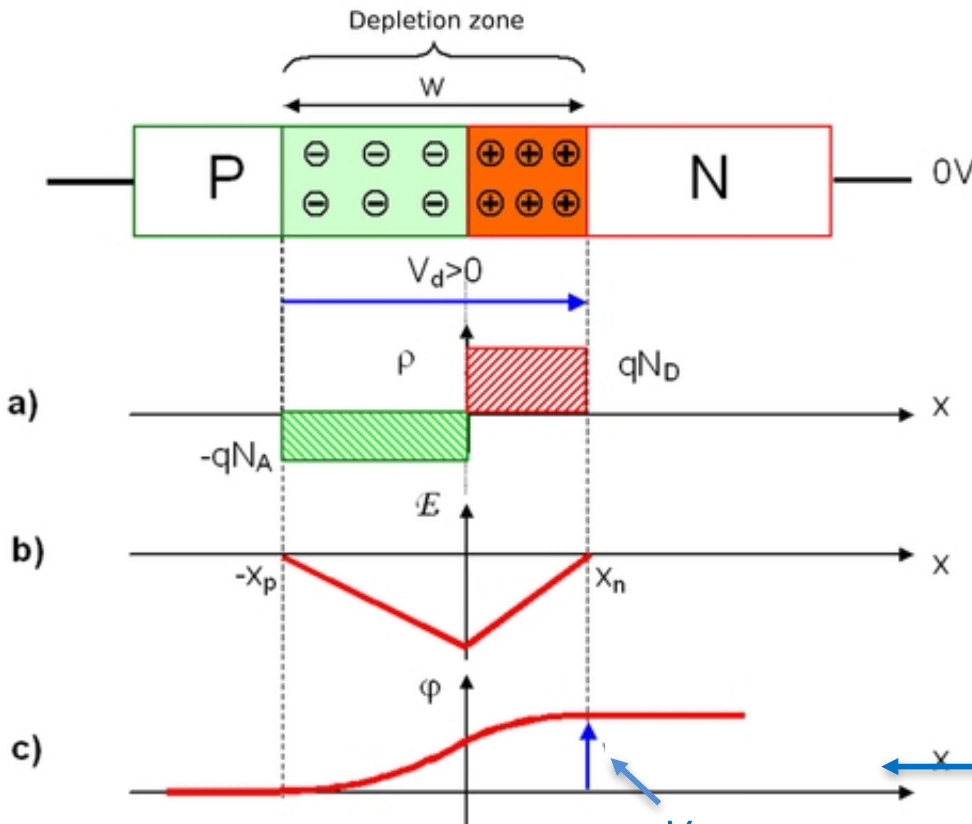
Notes:

Exam: Friday afternoon works for everyone. (Location TBA)

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.

Semiconductor p-n junctions:



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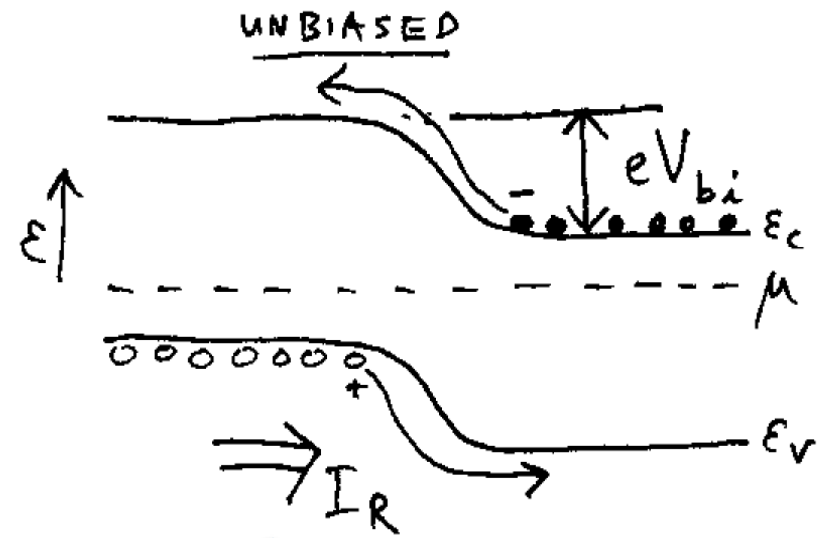
Bands scale according to local electric potential:



$$U_{\text{electrons}} = -eV_{\text{internal}}$$

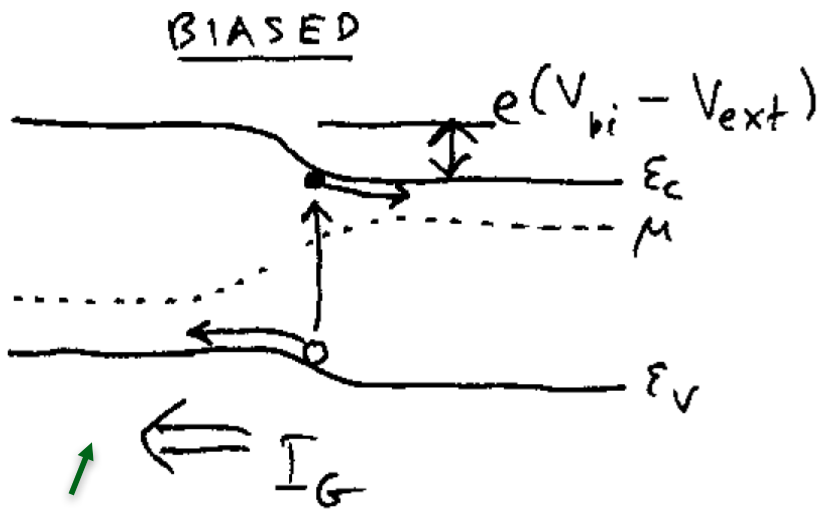
Note, chemical potential is what is measured externally

(e.g. with ideal voltmeter)

Also note, we assumed here *V* varies slowly.

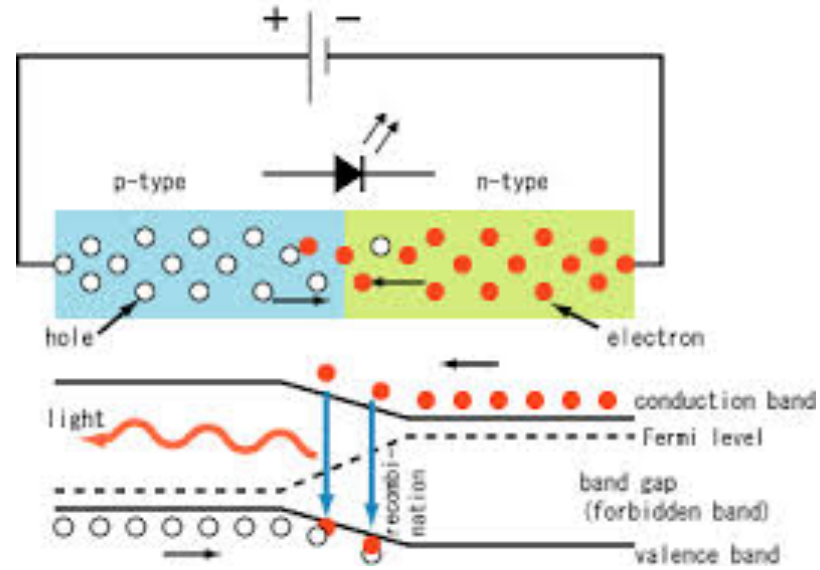
(OK if donor densities not too large)

Semiconductor LED & biased junction:

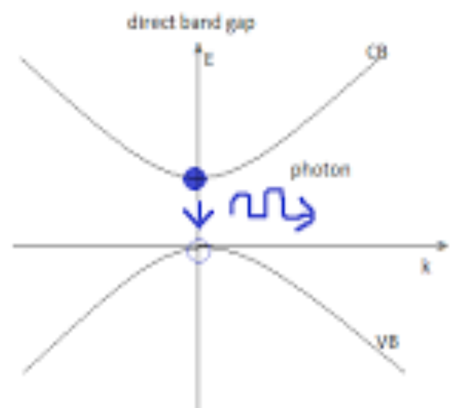


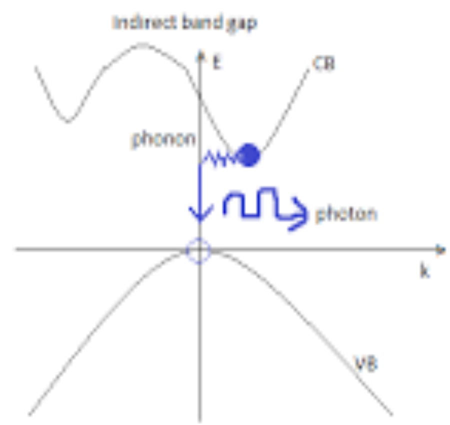
Biased: most of voltage drops over depletion region (high resistivity)

$$I = I_G\left(\exp[+V_{ext}/kT]-1\right)$$

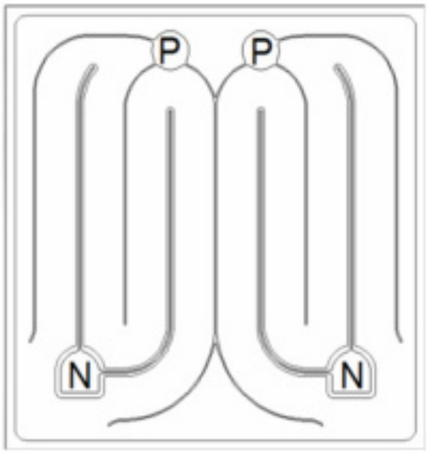


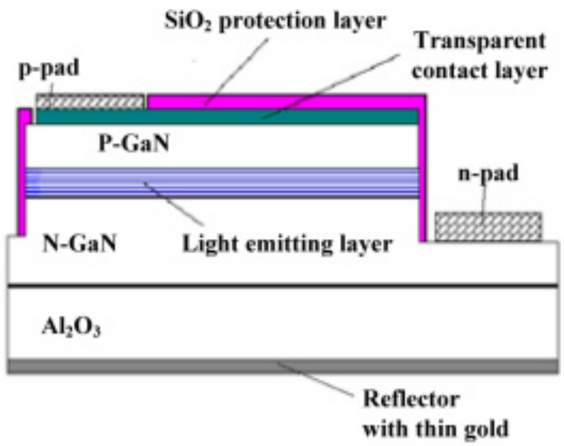
LED: Emission at gap energy, requires direct gap for efficient emission.

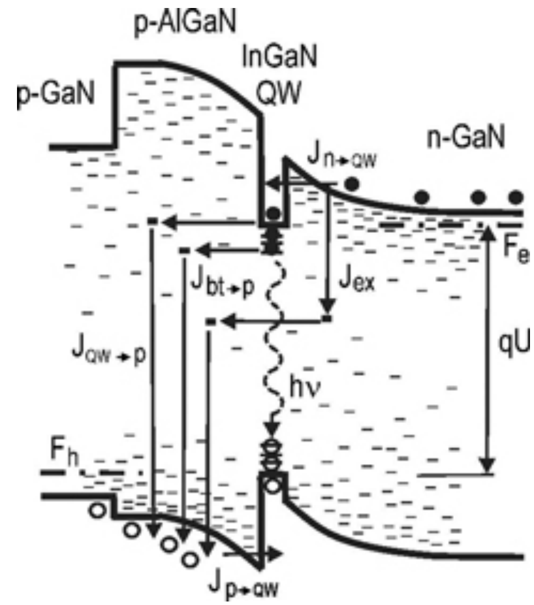




Blue LEDs:







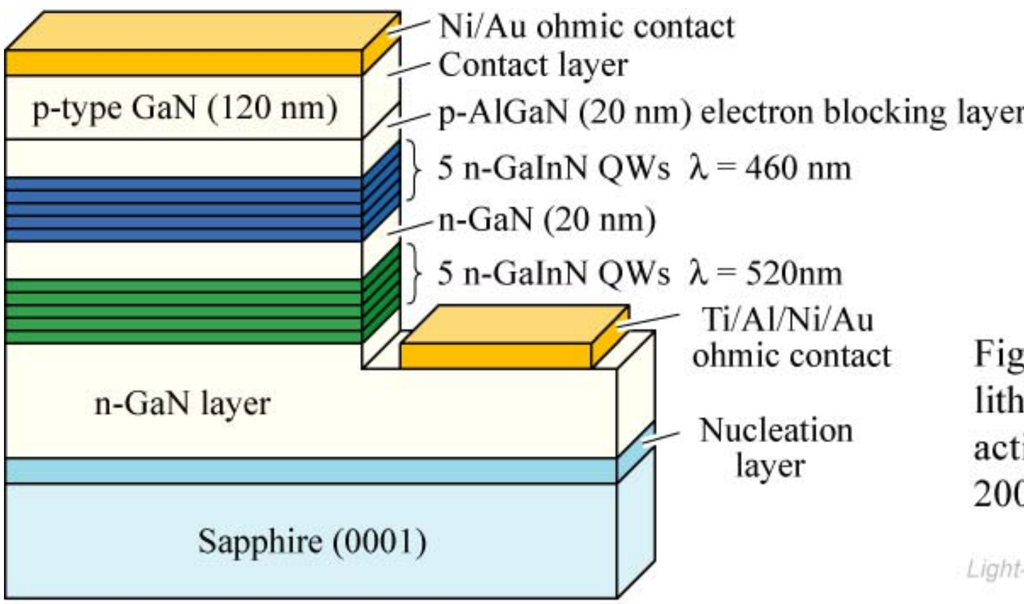
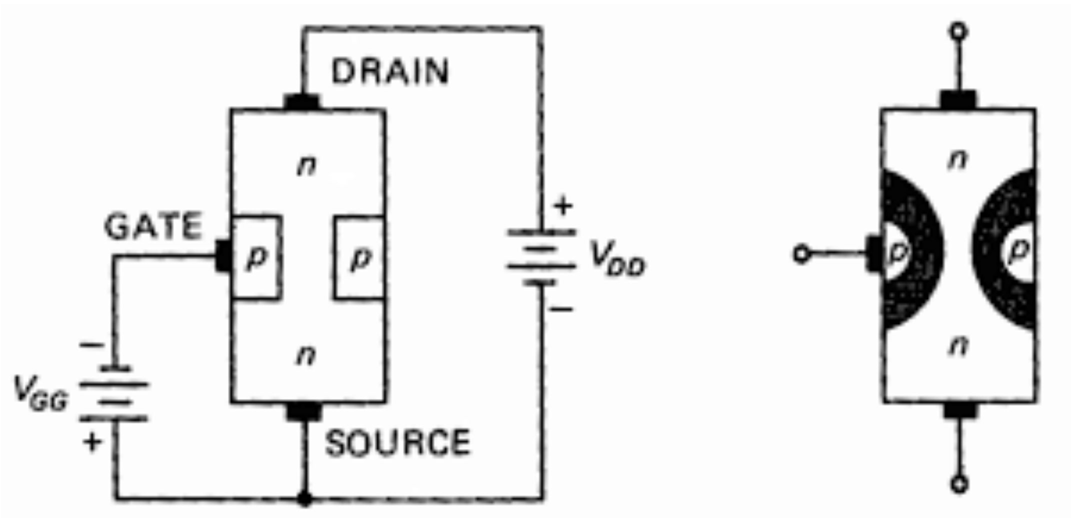


Fig. 20.4. Structure of a monolithic dichromatic LED with two active regions (after Li *et al.*, 2003).

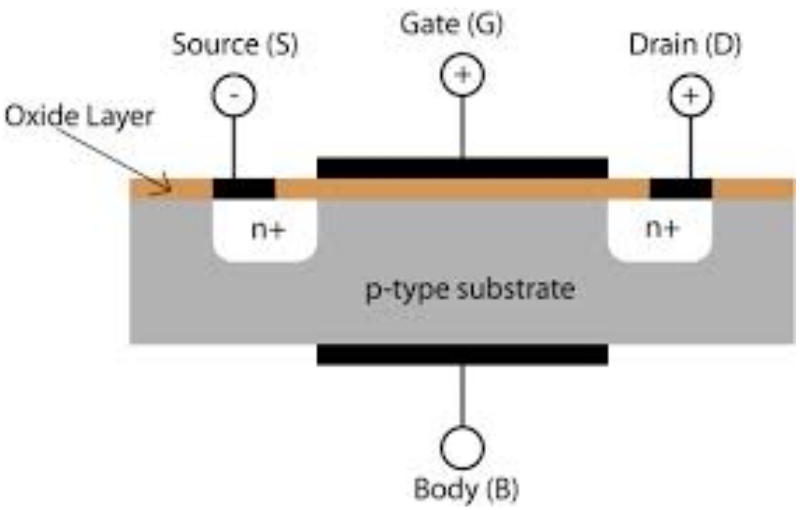
Field Effect Transistor

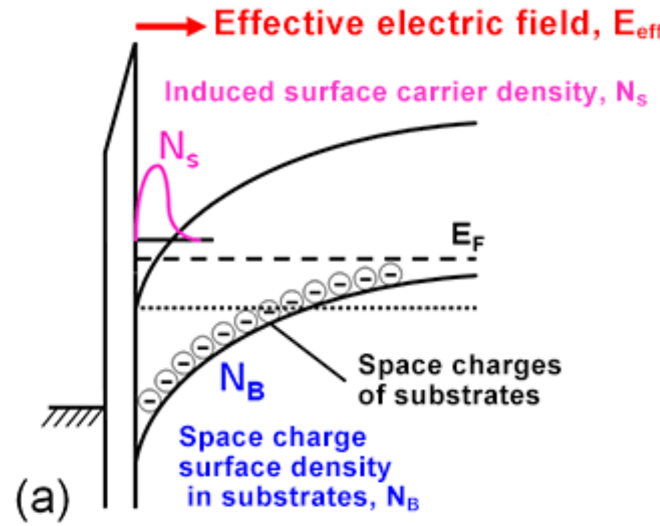


(a) (b)

JFET = Junction Field Effect Transistor
Voltage-controlled conductor = switch or amplifier

Silicon MOSFET:





MOSFET = Metal-Oxide-Silicon Field Effect Transistor
Widely used: high power switches, amplifiers, logic gates…

- Conduction in inversion layer at interface.
- Field due to applied gate voltage (plus surface charges).
  Gate electrically disconnected from device.

Silicon MOSFET:

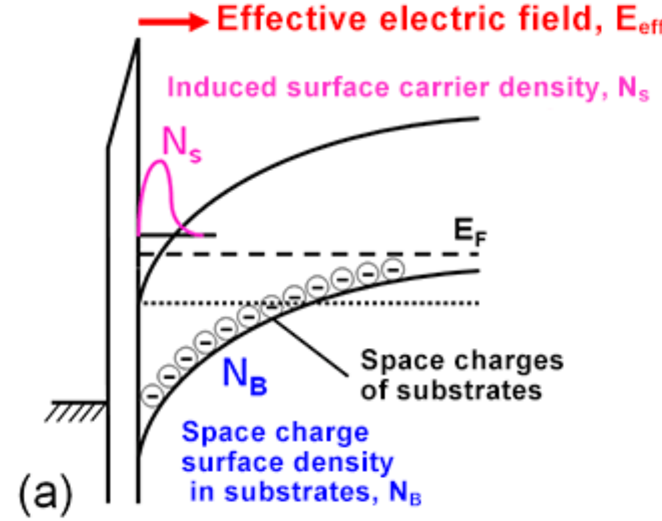
Triangle well: quantized 1D solutions in terms of Airy function;

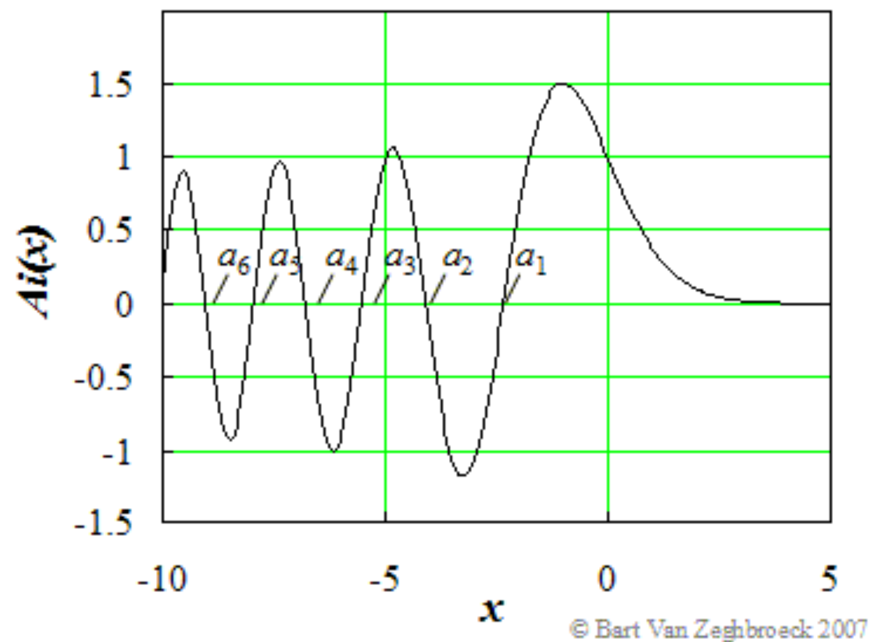
$$E_n = -\left[\frac{e^2 E^2 \hbar^2}{2m}\right]^{1/3} a_n$$

E = field at interface

$$E = \frac{10\ \text{V}}{1\ \mu\text{m}} \Rightarrow E_1 \approx 15\ \text{meV}$$
$$(\text{m}^* = 1)$$

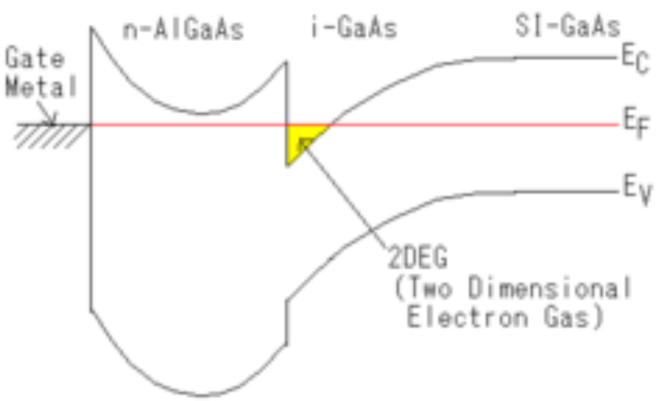
Single 2D electron gas state, if E_{2+} not occupied.
At low T typically degenerate Fermi gas.



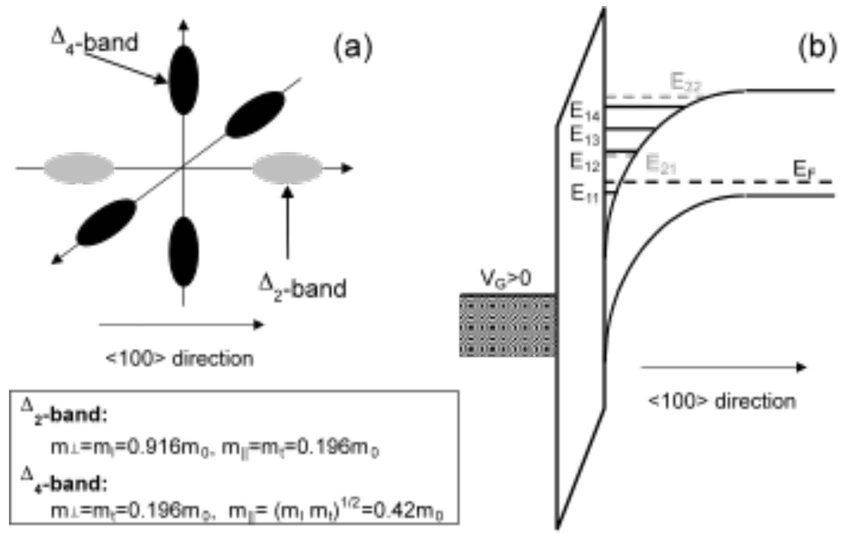


Ref B. Van Zegbroeck Principles of Semiconductor Devices

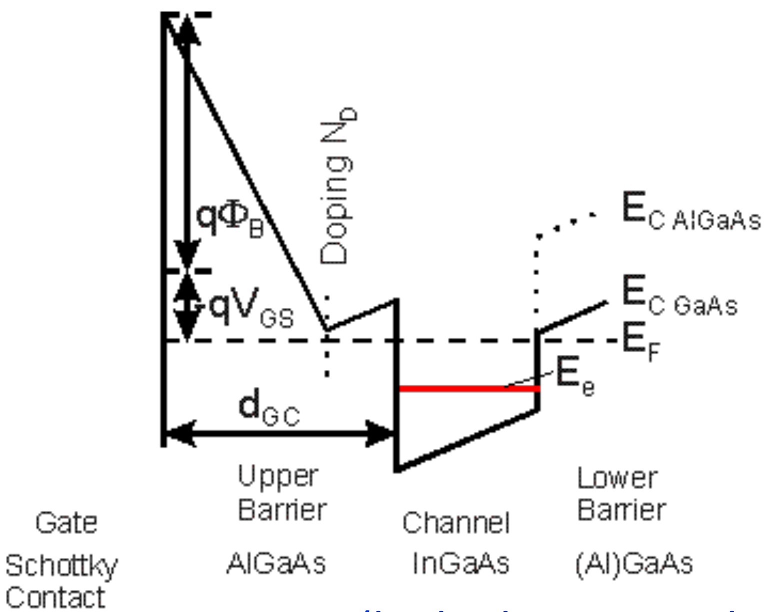
2DEG structures etc:

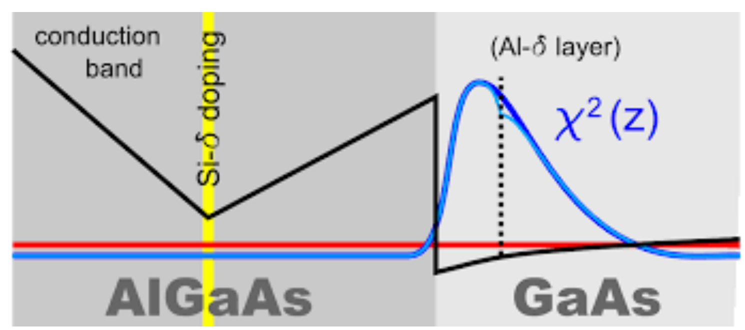


GaAs-AlGaAs structure



Si MOSFET and confinement vs. electron pocket





HEMT (high electron mobility transistor); delta-doping

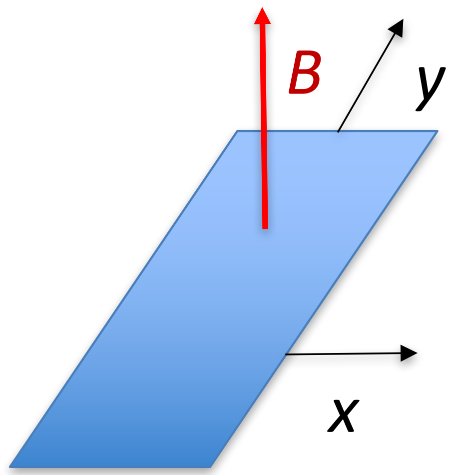
2D Quantized states in magnetic field

Neglect V here, assume *m* is effective mass.

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

recall

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



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

Gives 2DSHO solution, "circulating" solutions

1DSHO, "traveling" solutions

Equivalent solutions, with degeneracy *B*×(Area)/Φ_o per Landau Level.

More general $k \to i\nabla$

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

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

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

Solutions: Landau orbitals, in degenerate Landau levels E_n.