# EE 105

# Semiconductors

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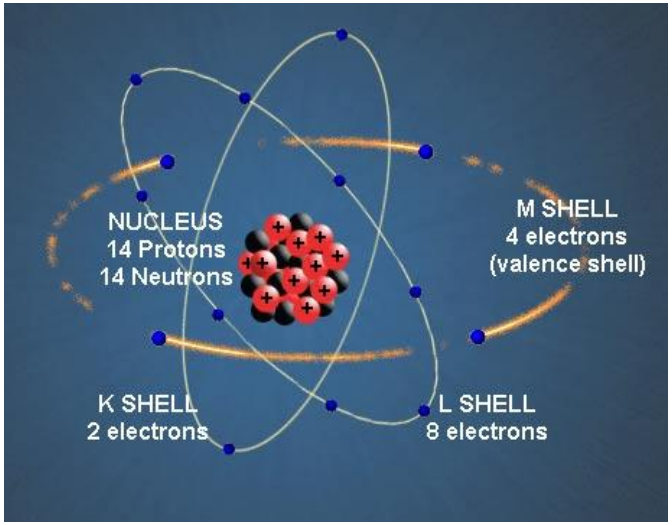
# Active Devices

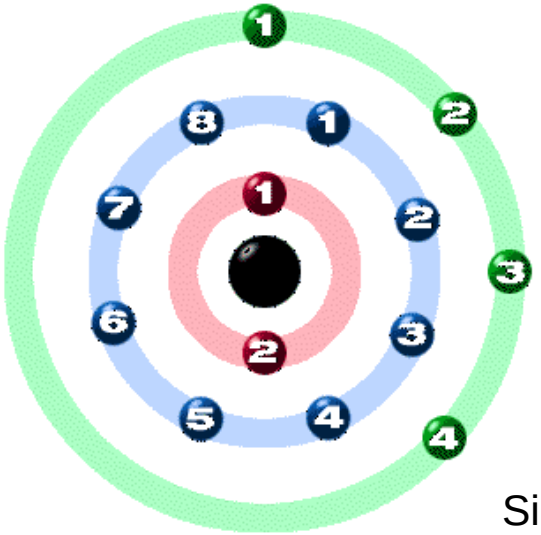
- Control (current) flow
- Cascadeable:
  - Compatible inputs and outputs including
  - Same physical domain, e.g.
    - Electrical
    - Pneumatic
    - Chemical
    - Mechanical
  - Compatible signal levels, e.g.
    - Switch with 5V control signal must be able to switch 5V at output
- Examples:
  - Transistor
  - Relays
  - Vacuum tube

# Semiconductors

# Electrical Conduction

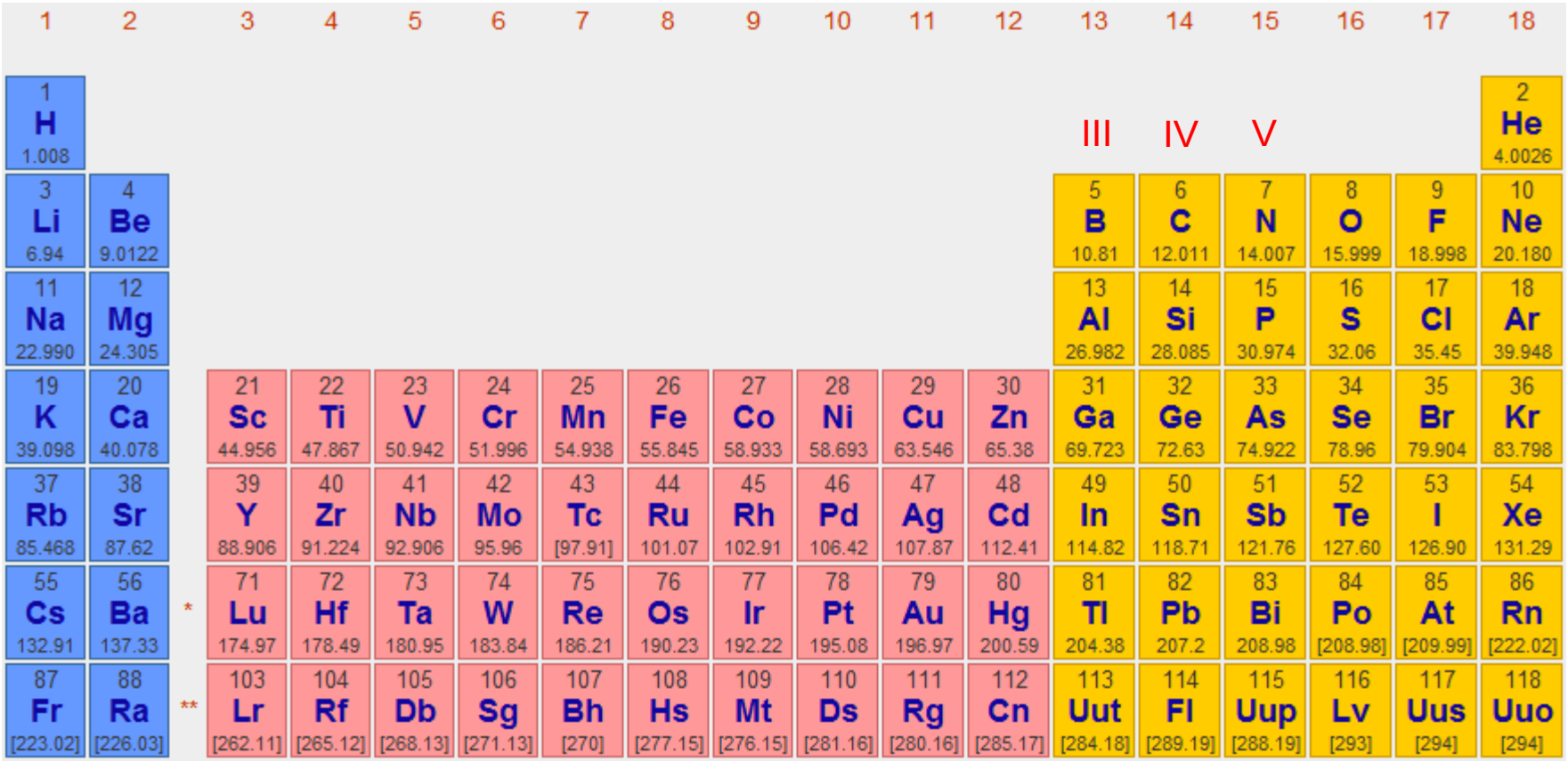
# Atom Shells



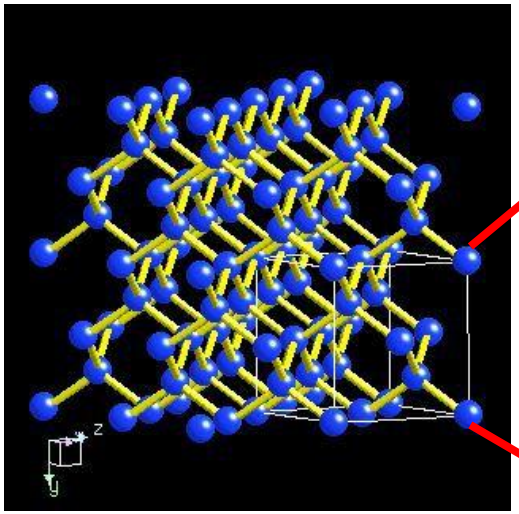

Si

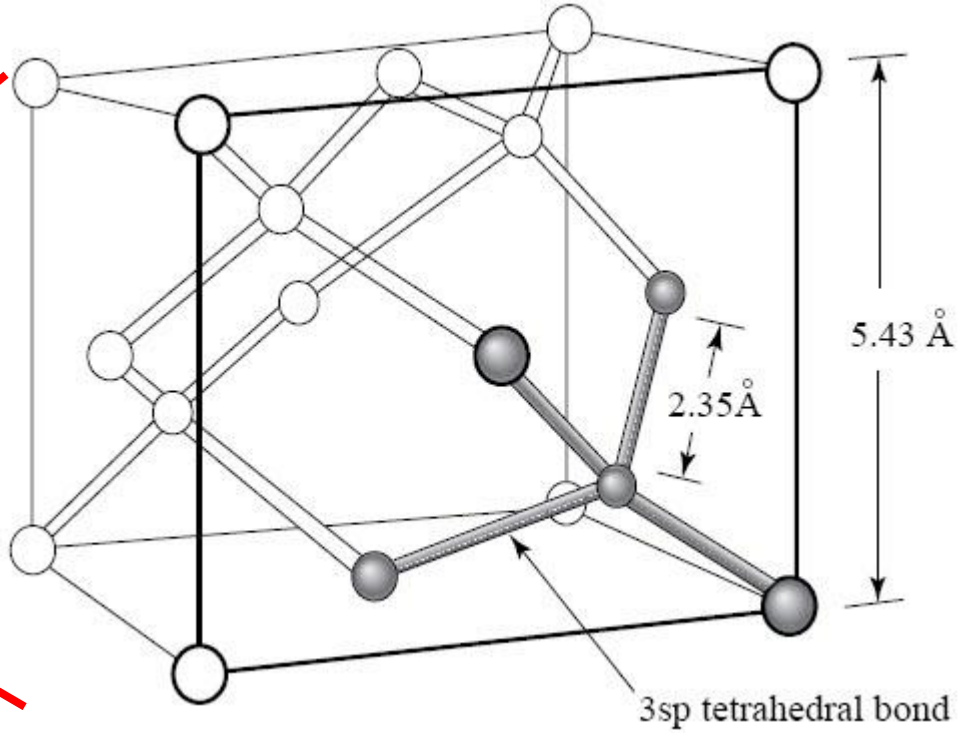
# Semiconductors



# Silicon Crystal

# Silicon Crystal

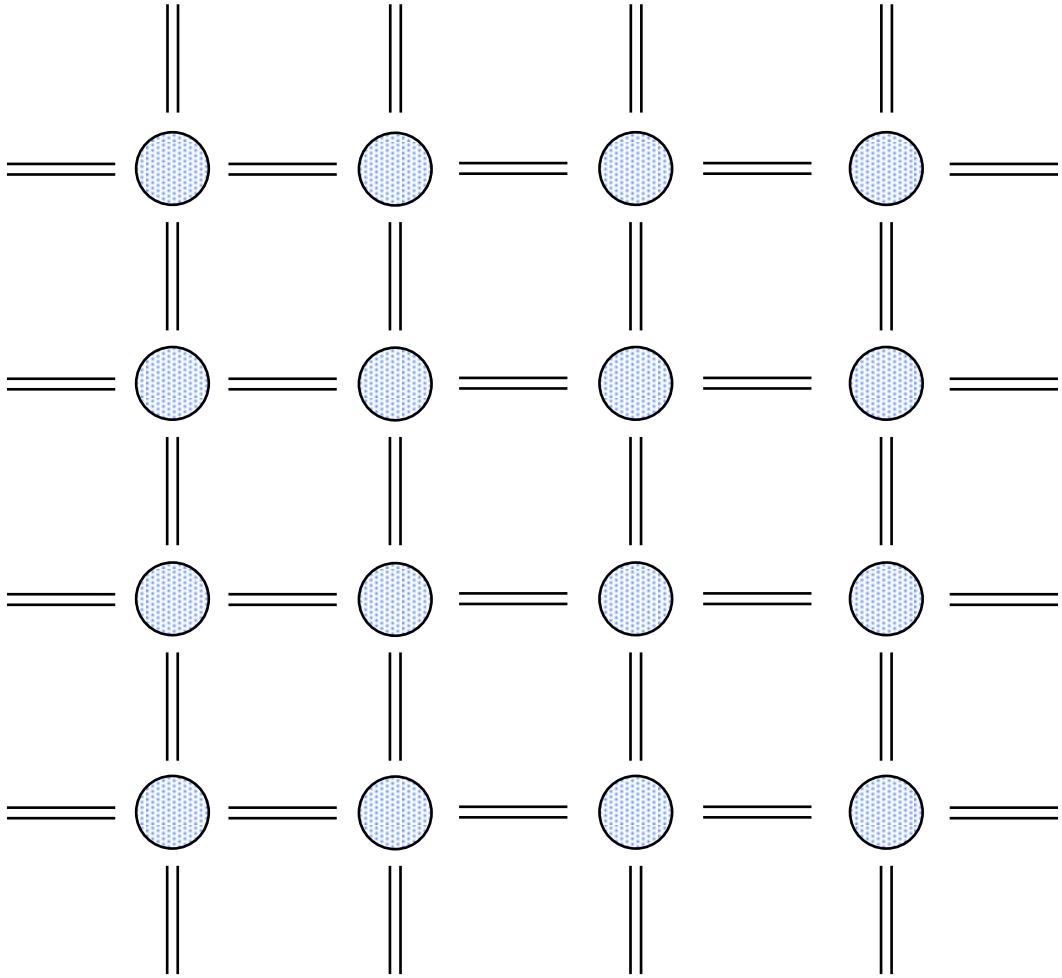




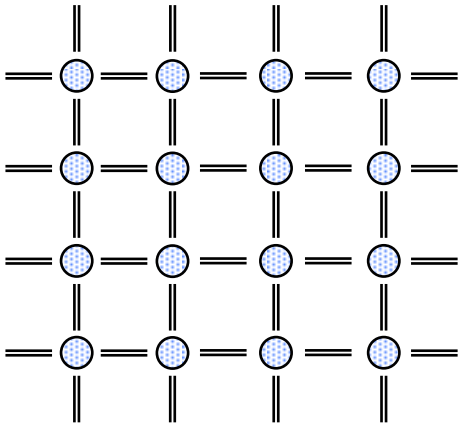

Density:
$5 \times 10^{22}$ atoms / $cm^3$

Distance between atoms:
0.235 nm

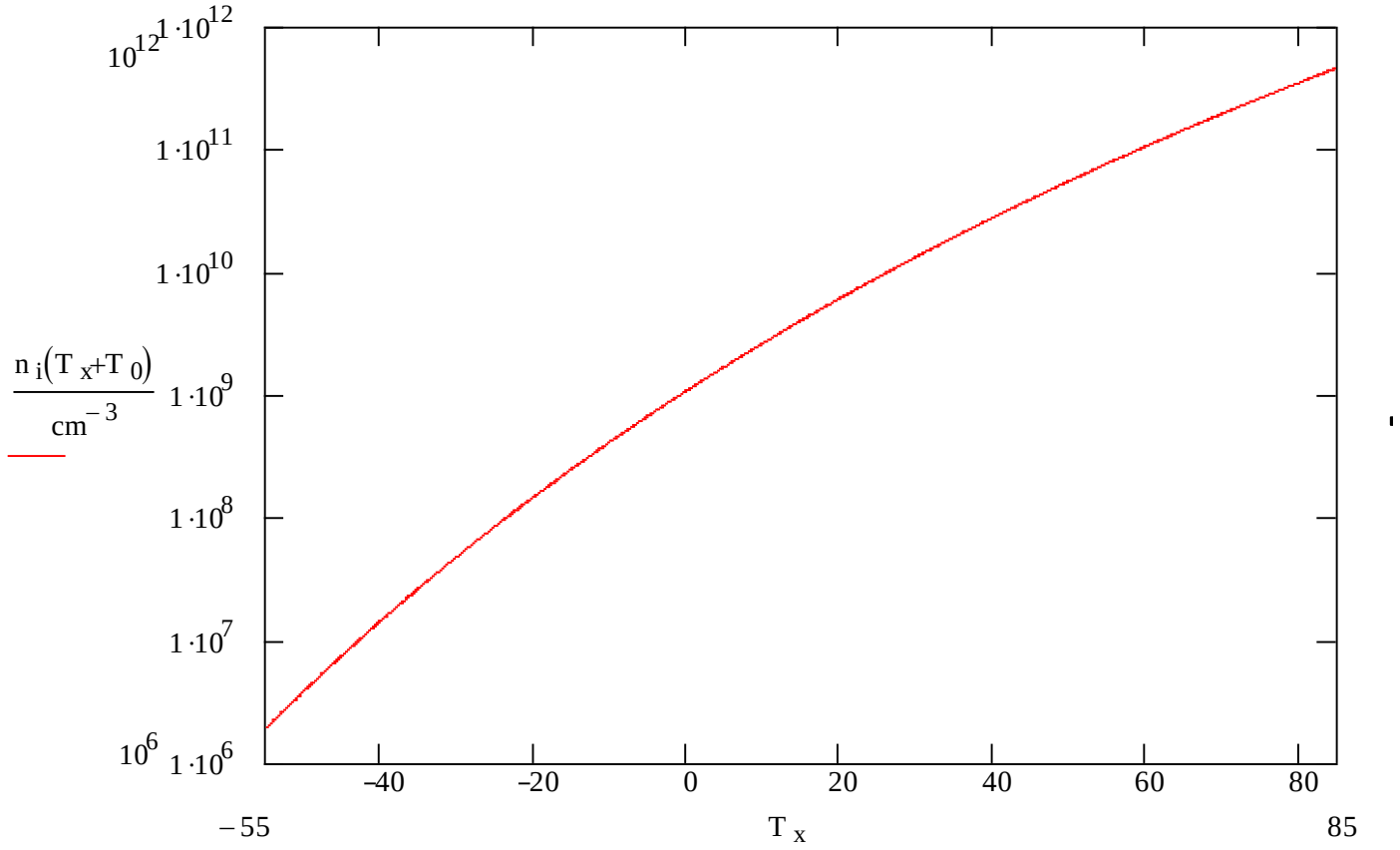
# 2D Representation for Simplicity



# Bandgap



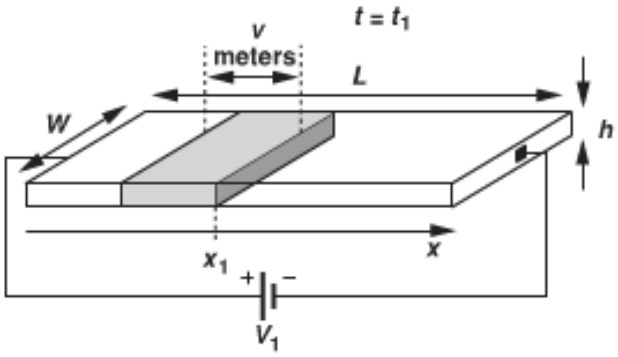
# Intrinsic Carrier Concentration $n_i$



# Semiconductors Summary

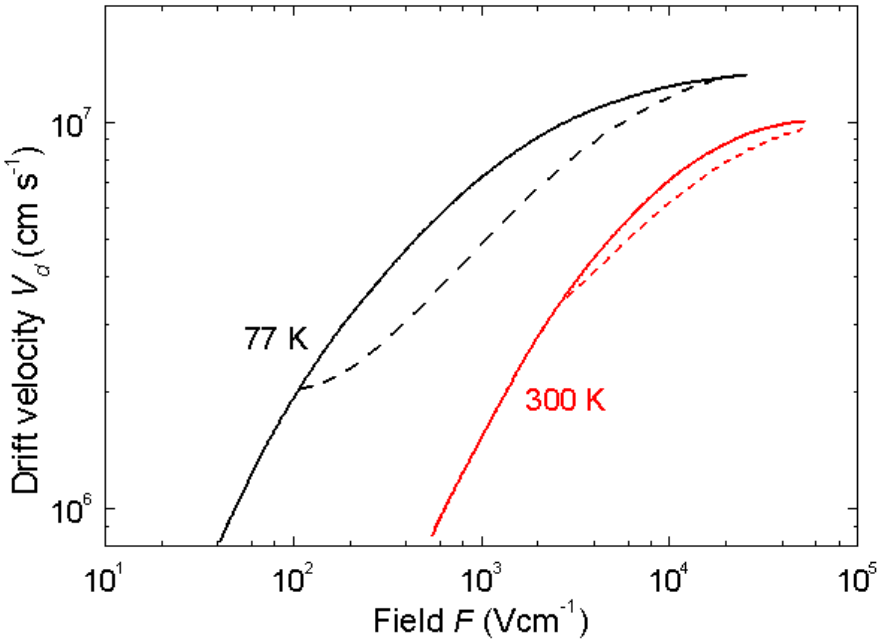
# Drift Current

# Current Flow



# Mobility

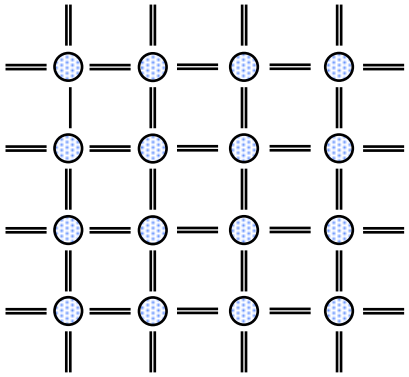
Jacoboni, C., C. Canali, G. Ottaviani, and A. A. Quaranta, *Solid State Electron.* **20, 2**(1977) 77-89.

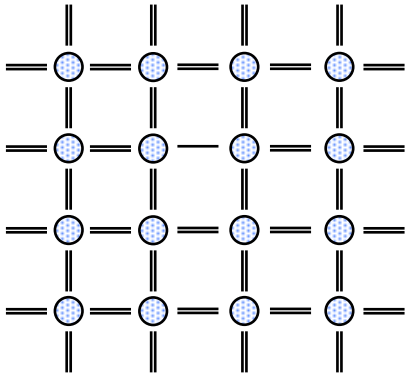


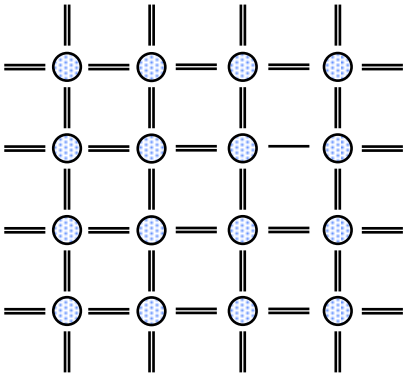

Electron drift velocity in Si

# Drift Current Example

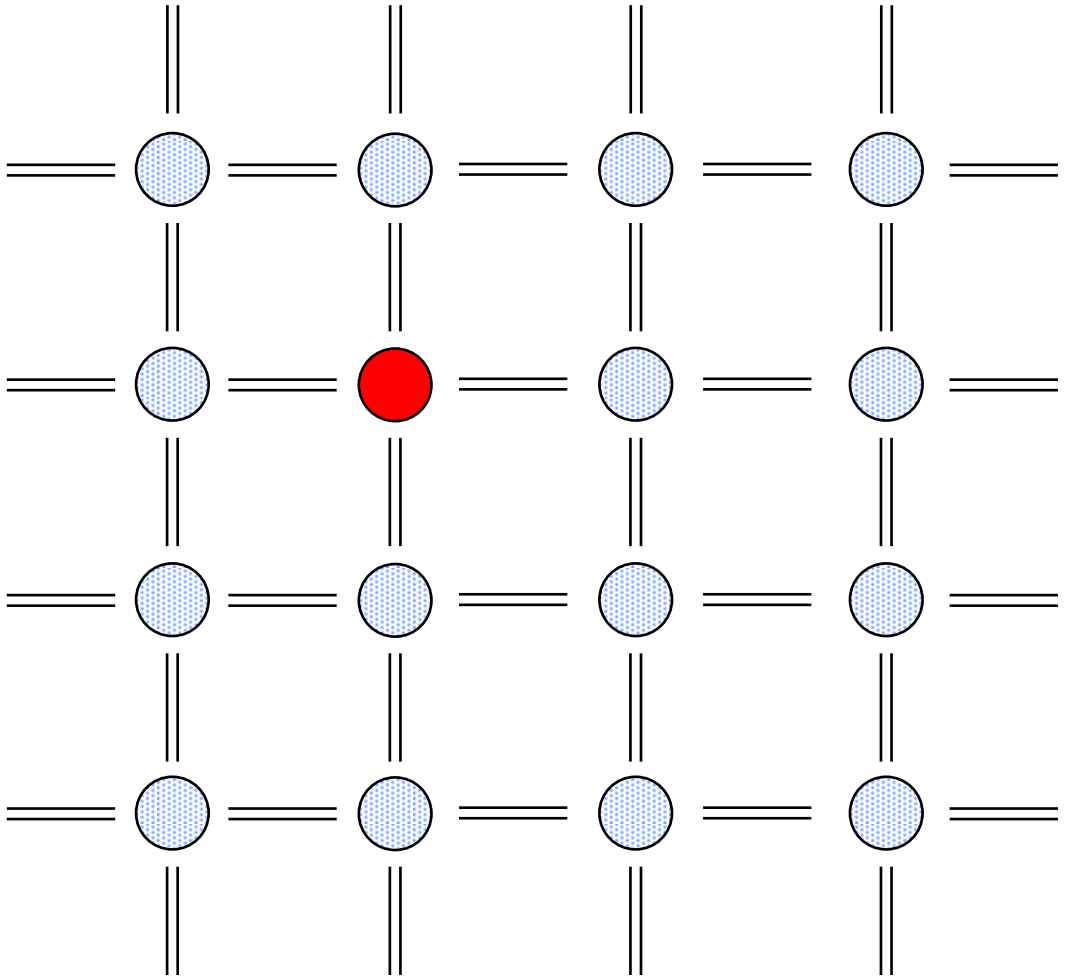
# Holes



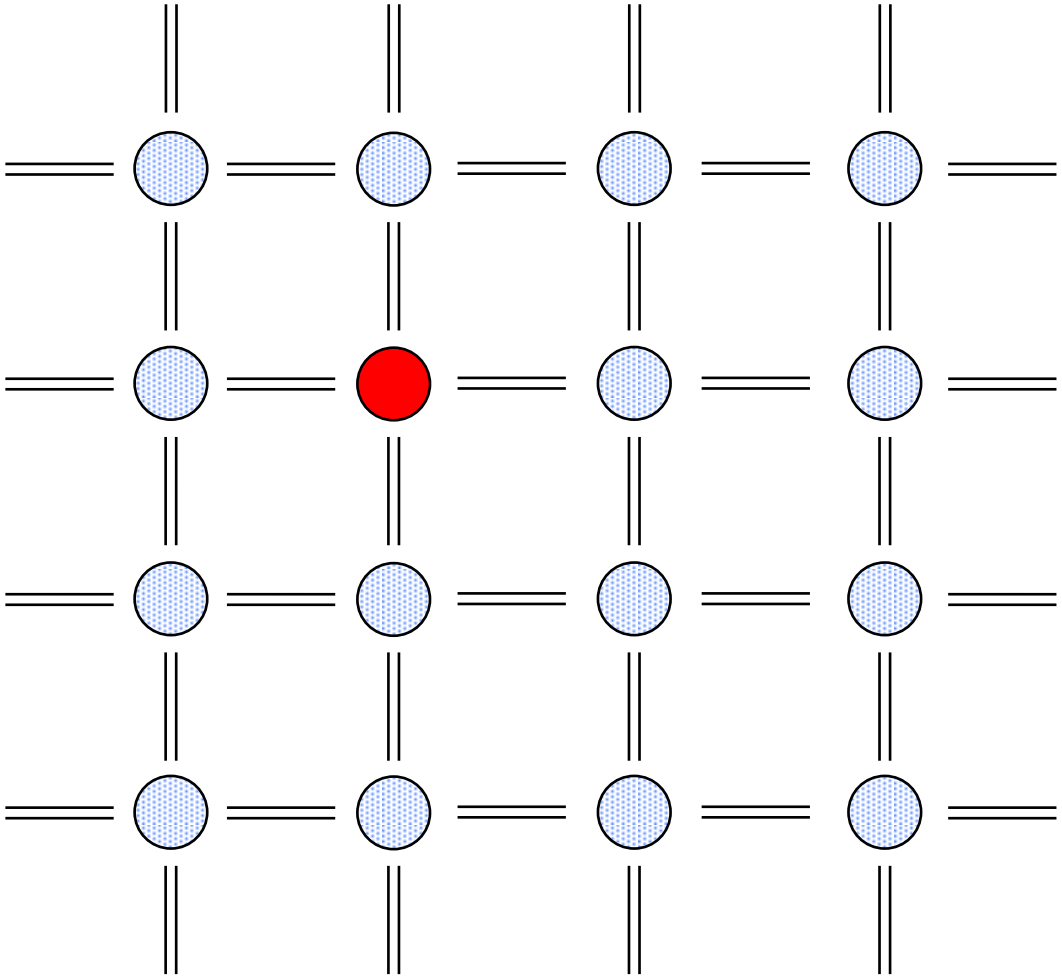




# "~~Semi~~" Conductor?



# Donors



# Question

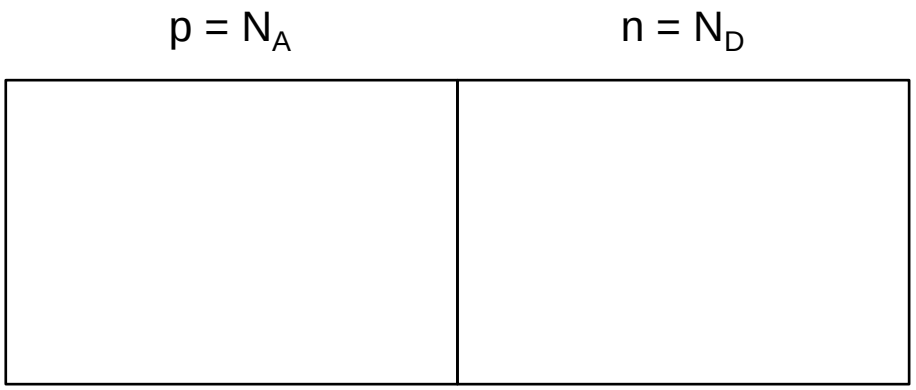
Is a doped semiconductor charge neutral?

# Uniform Semiconductors Summary

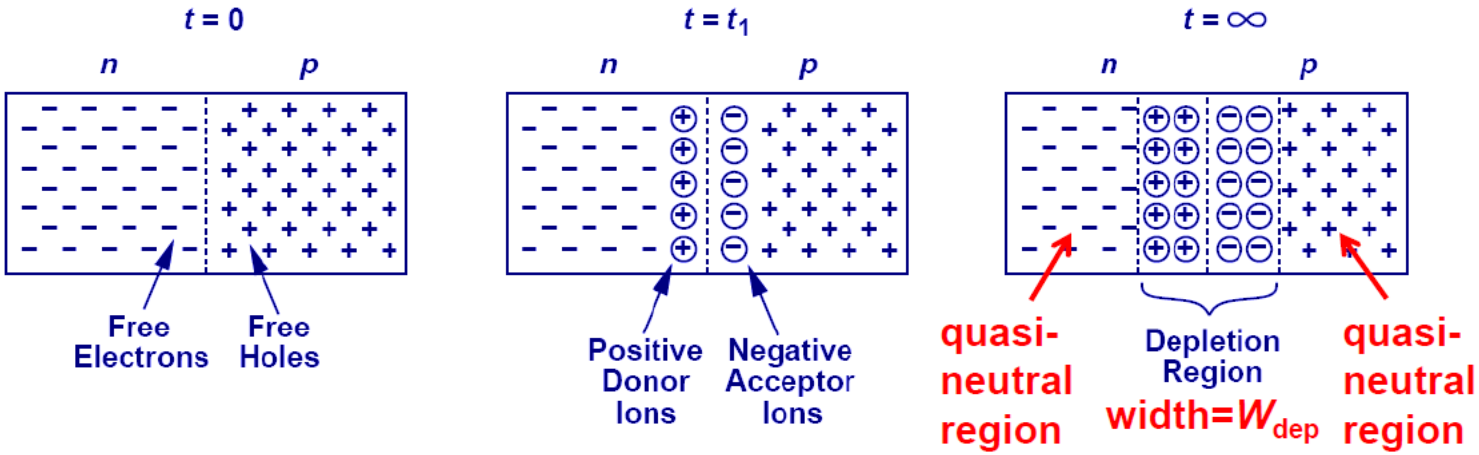
# *pn* Junction

# (Diode)

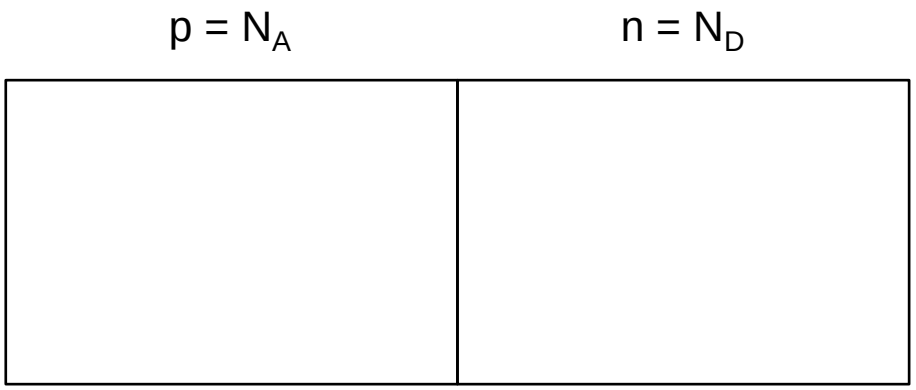
# *pn* Junction



# Depletion Region



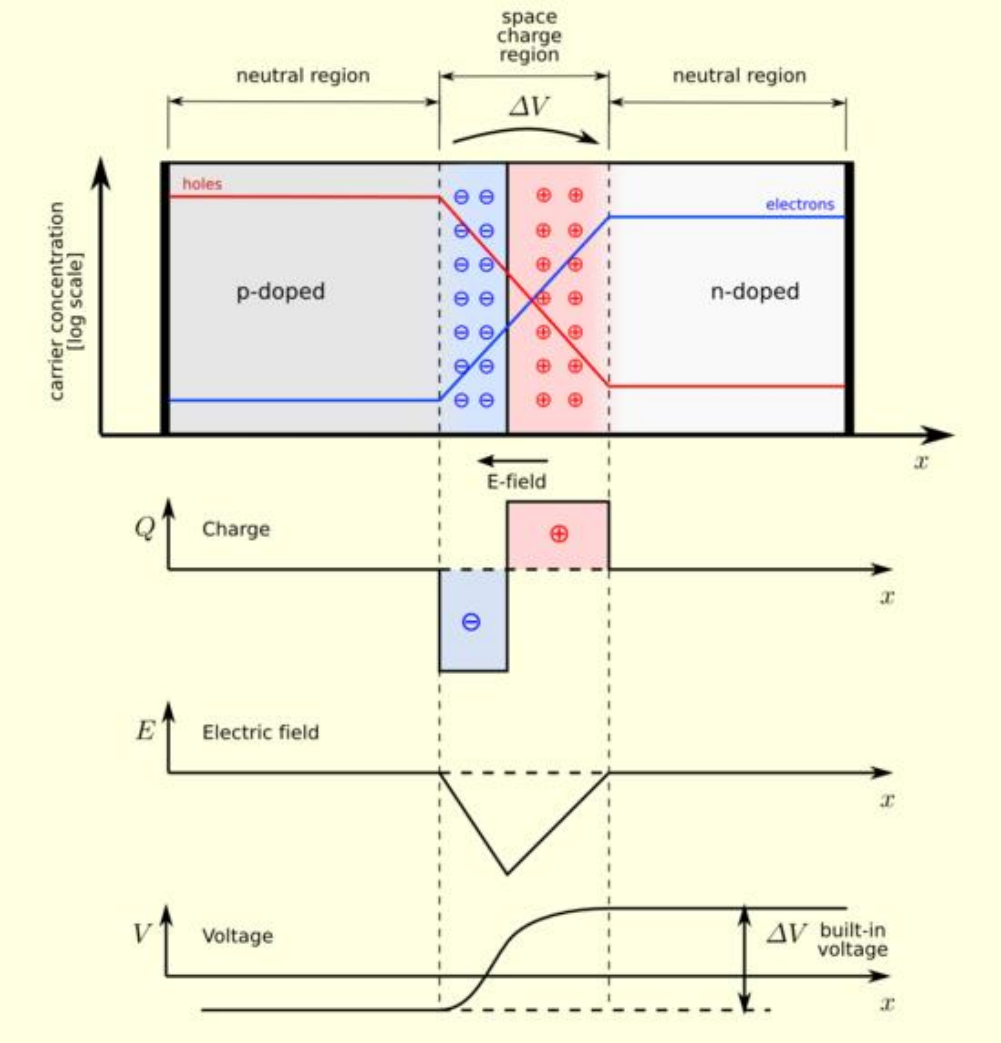
# Drift and Diffusion Currents




$I_{diffusion,n}$

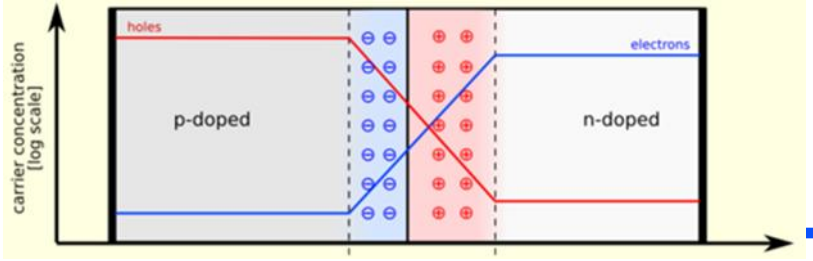
$+ I_{drift,n} = 0A$

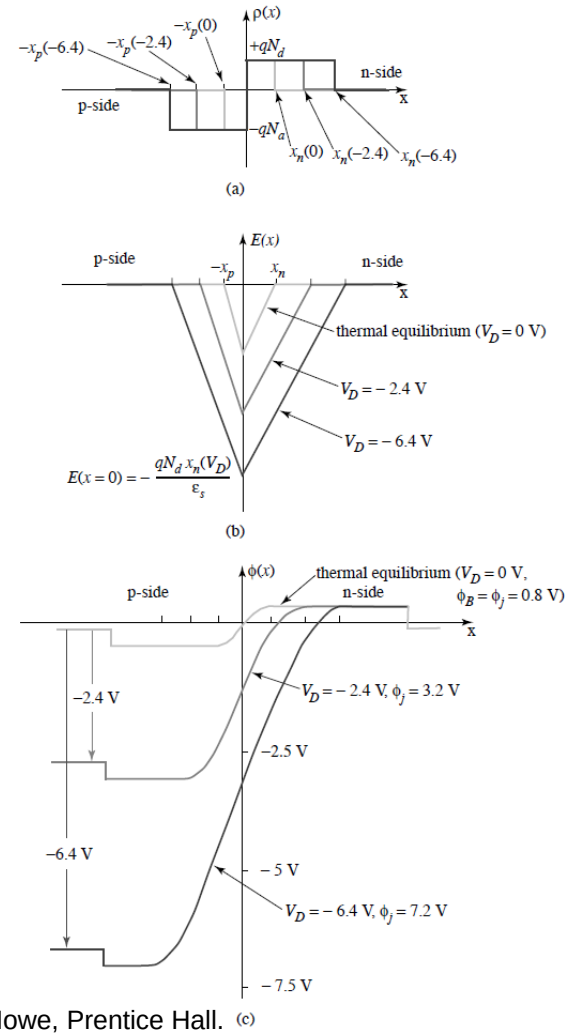
# Junction Potential

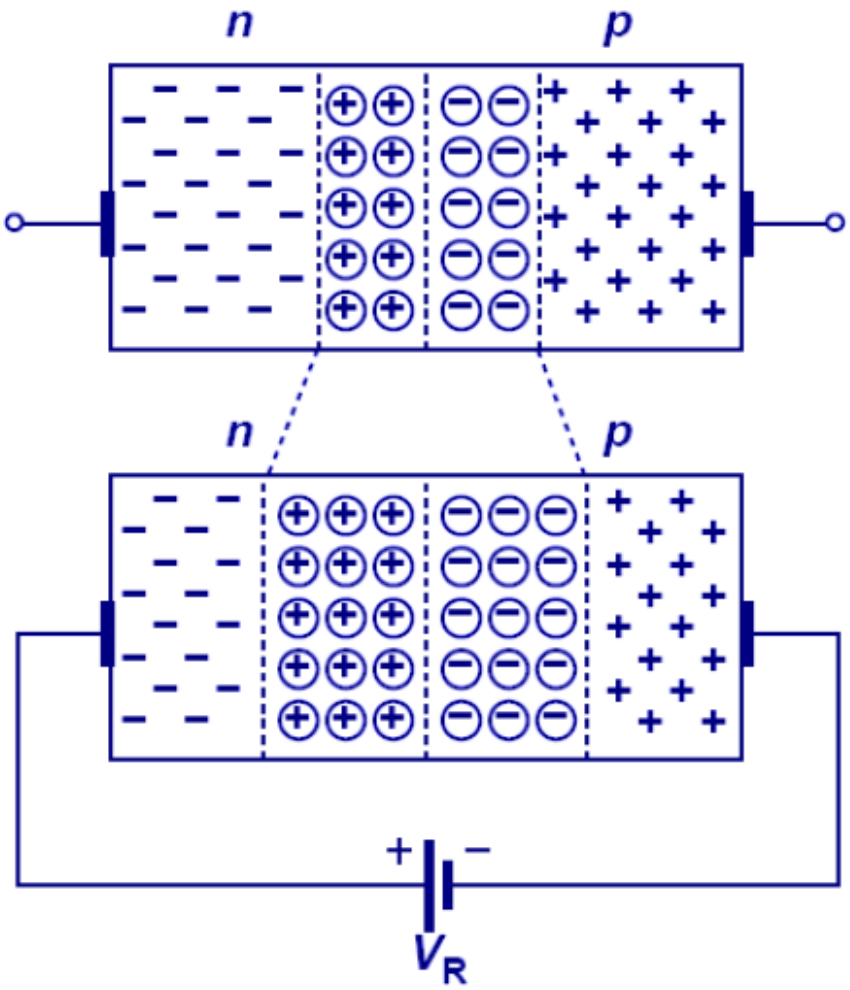



http://en.wikipedia.org/wiki/P-n_junction

# Reverse Bias

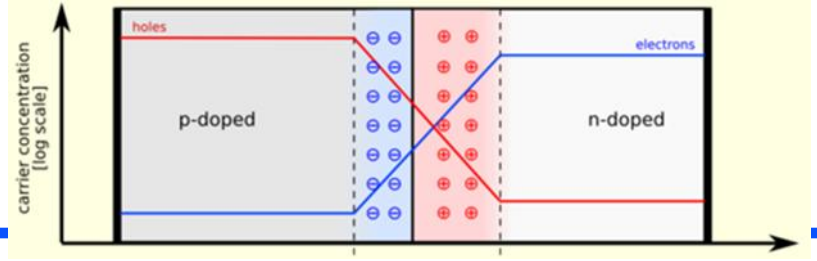


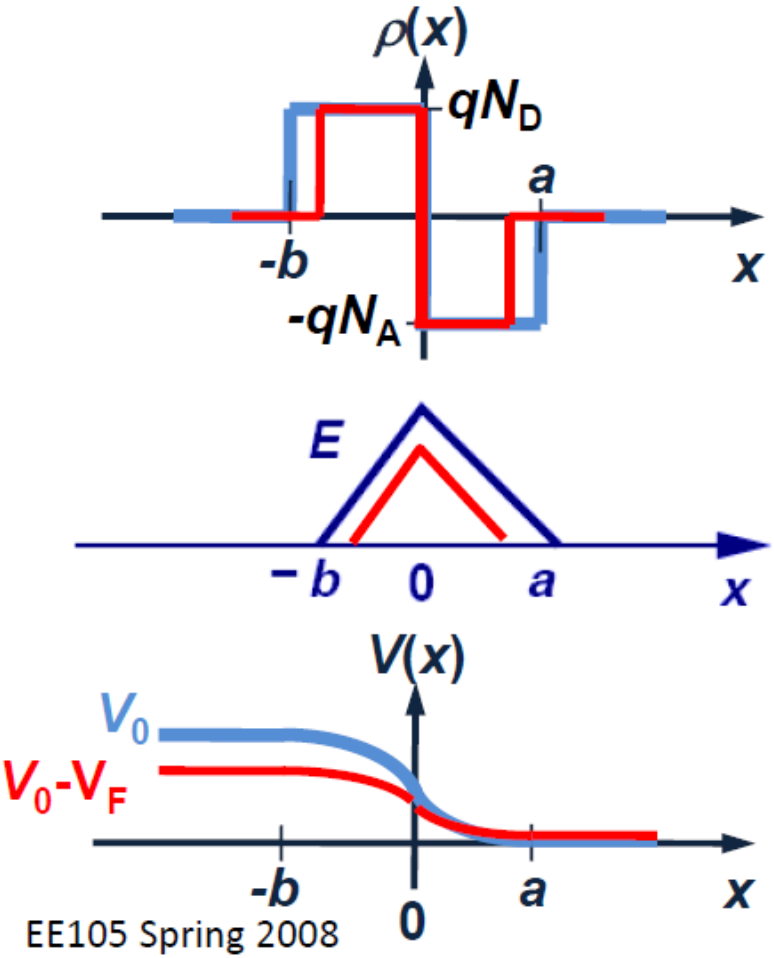



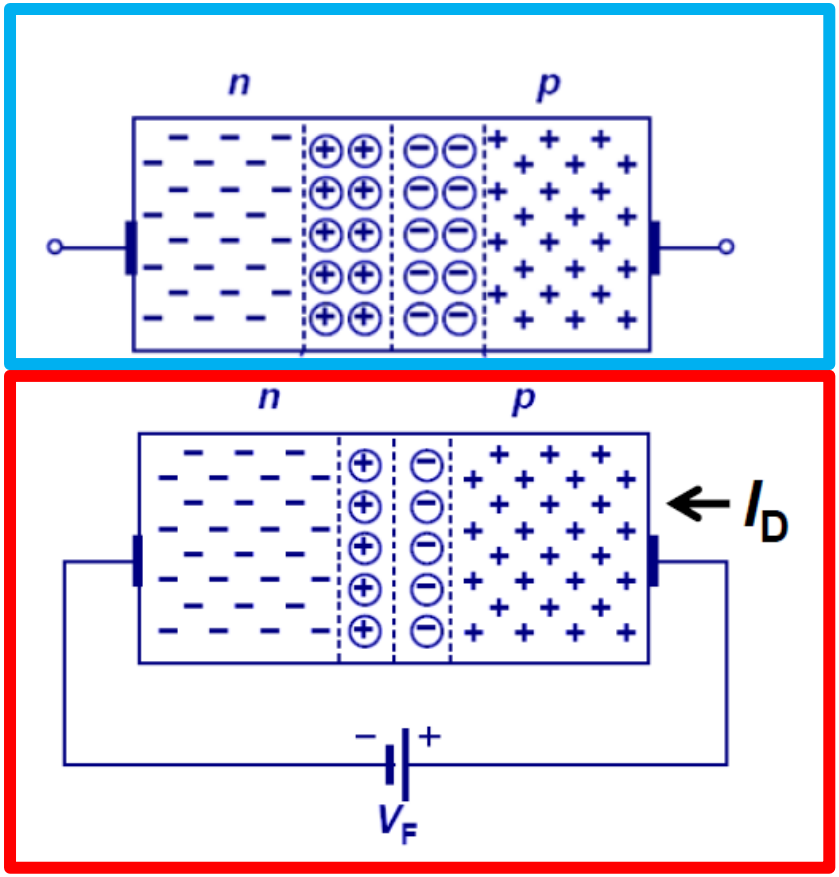




Ref: R. Howe, Prentice Hall.

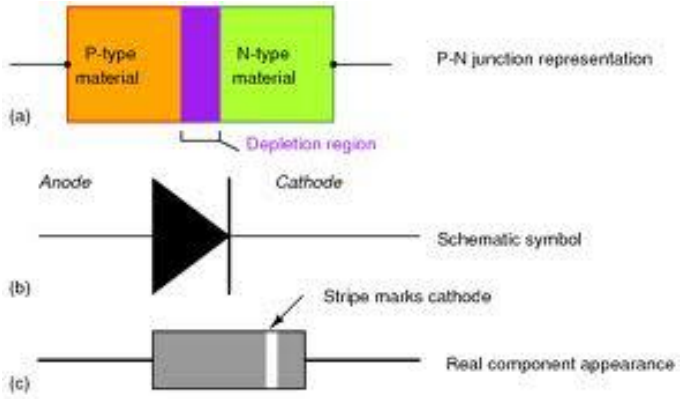
# Forward Bias

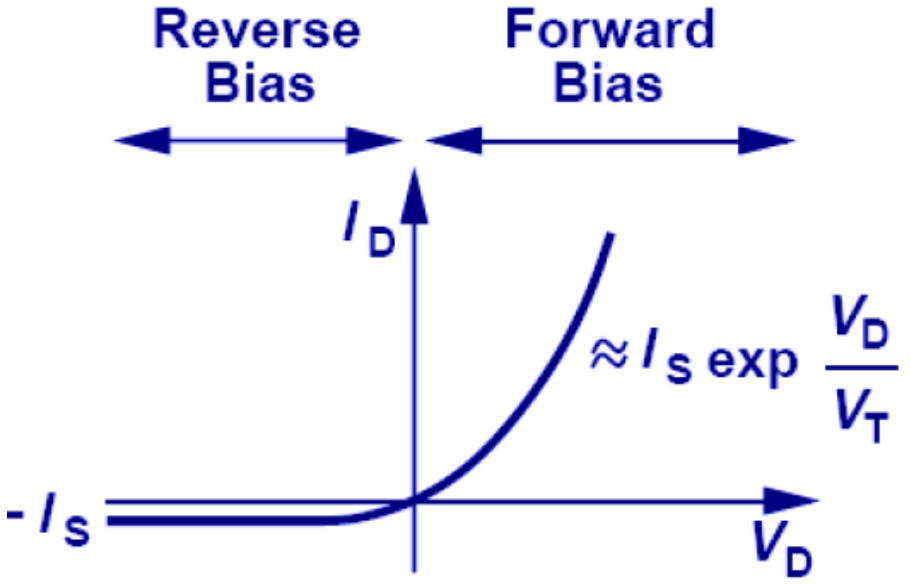


# Putting it all Together




**"Ideal diode" equation:**

$$I_D = I_S\left(e^{V_D/V_T} - 1\right)$$

$$I_S = AJ_S = Aqn_i^2\left(\frac{D_n}{N_A L_n} + \frac{D_p}{N_D L_p}\right)$$