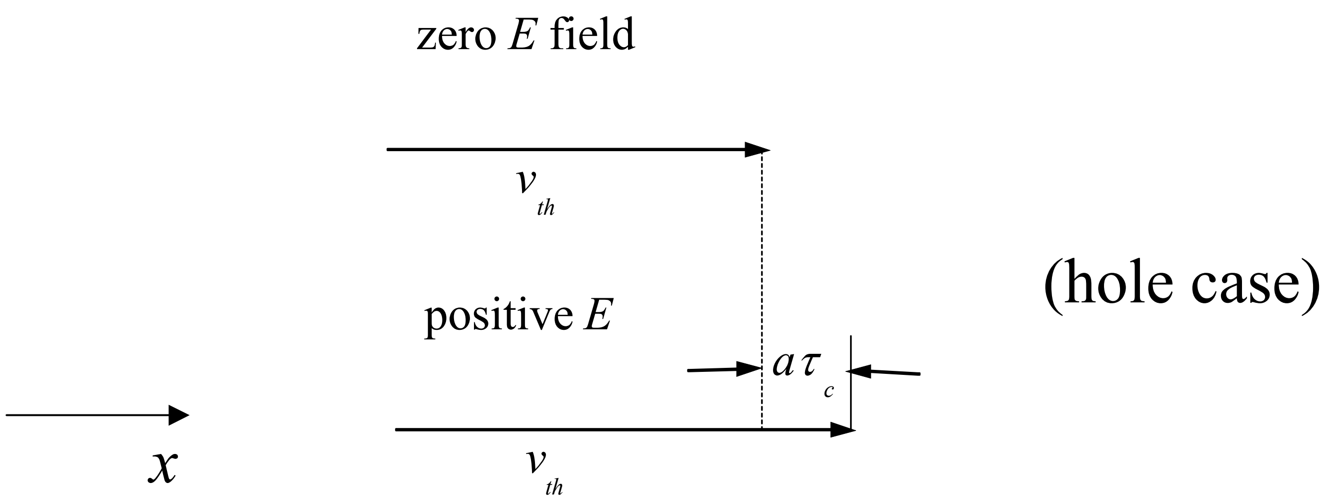
Lecture 8

- Last time:
  - Wrap-up phasor analysis: 2^{nd} order circuits
  - Start semiconductor properties of Si
- Today :
  - Drift velocity
  - Drift current density
  - Resistivity and resistance

Thermal Equilibrium

Rapid, random motion of holes and electrons at "thermal velocity" $v_{th} = 10^7$ cm/s with collisions every $\tau_c = 10^{-13}$ s.

Apply an electric field E and charge carriers accelerate … for τ_c seconds



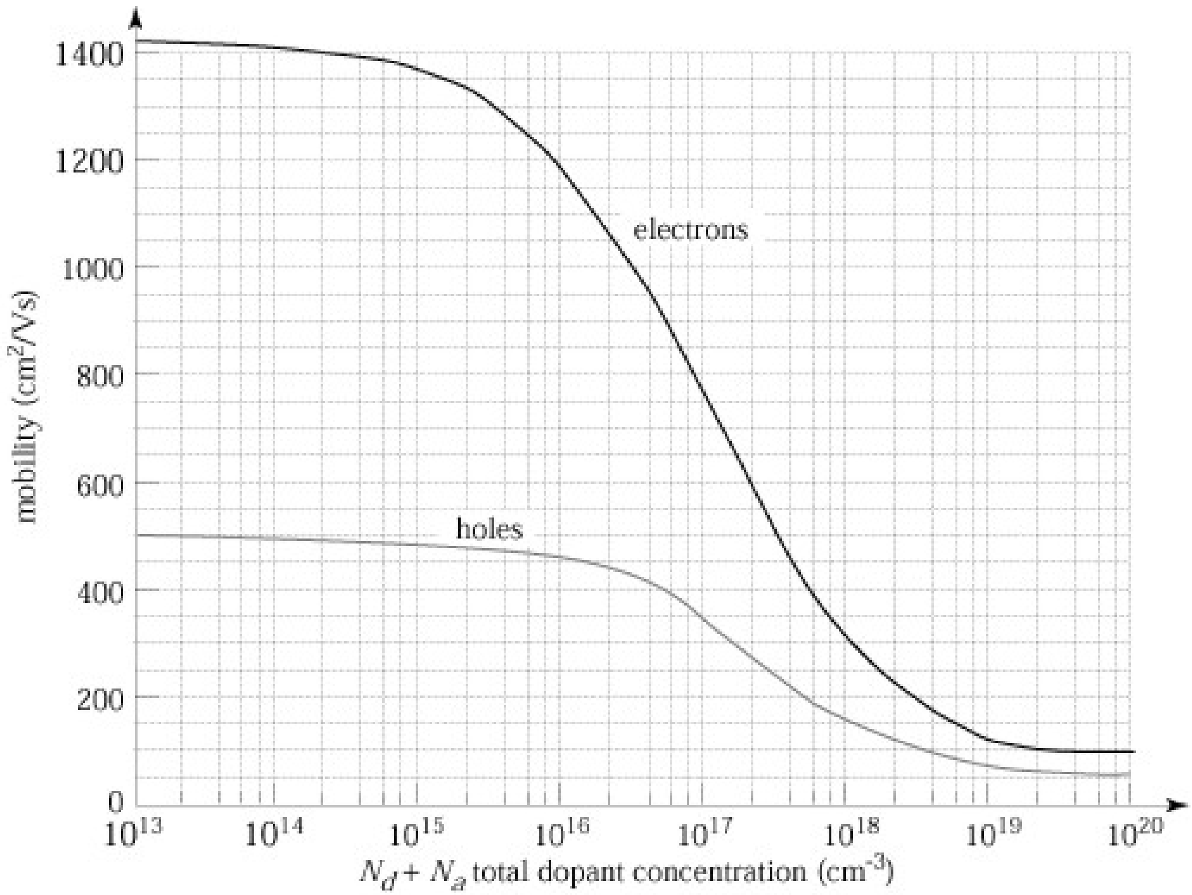
Drift Velocity and Mobility

$$v_{dr} = a \cdot \tau_c = \left(\frac{F_e}{m_p} \right) \tau_c = \left(\frac{qE}{m_p} \right) \tau_c = \left(\frac{q\tau_c}{m_p} \right) E$$

$$v_{dr} = \mu_p E$$

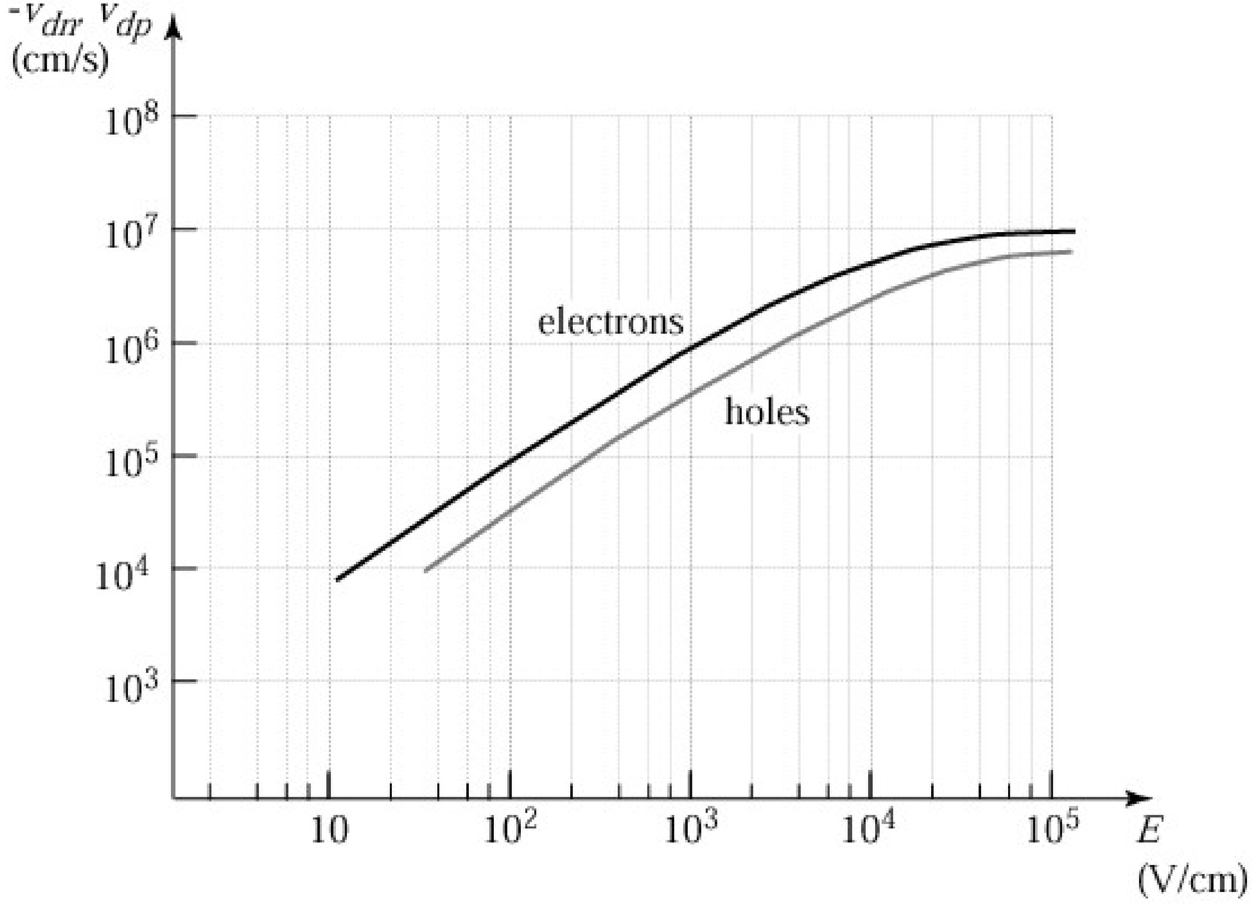
For electrons:

Mobility vs. Doping in Silicon at 300 K



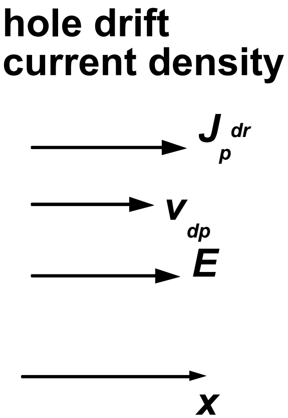
"default" values:

Velocity Saturation



Drift Current Density (Holes)

Hole case: drift velocitv is in same direction as E

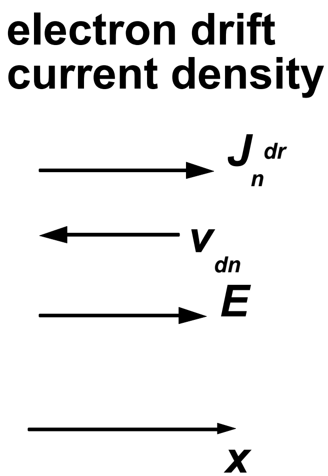


The hole drift current density is:

$$J_p^{dr} = q\, p\, \mu_p\, E$$

Drift Current Density (Electrons)

Electron case: drift velocity is in *opposite* direction as E



$$J_n^{dr} =$$

The electron drift current density is:

$$J_n^{dr} = (-q)\, n\, v_{dn}$$

units: $\text{Ccm}^{-2}\ \text{s}^{-1} = \text{Acm}^{-2}$

Resistivity

Bulk silicon: uniform doping concentration, away from surfaces

n-type example: in equilibrium, $n_o = N_d$.

When we apply an electric field, $n = N_d$.

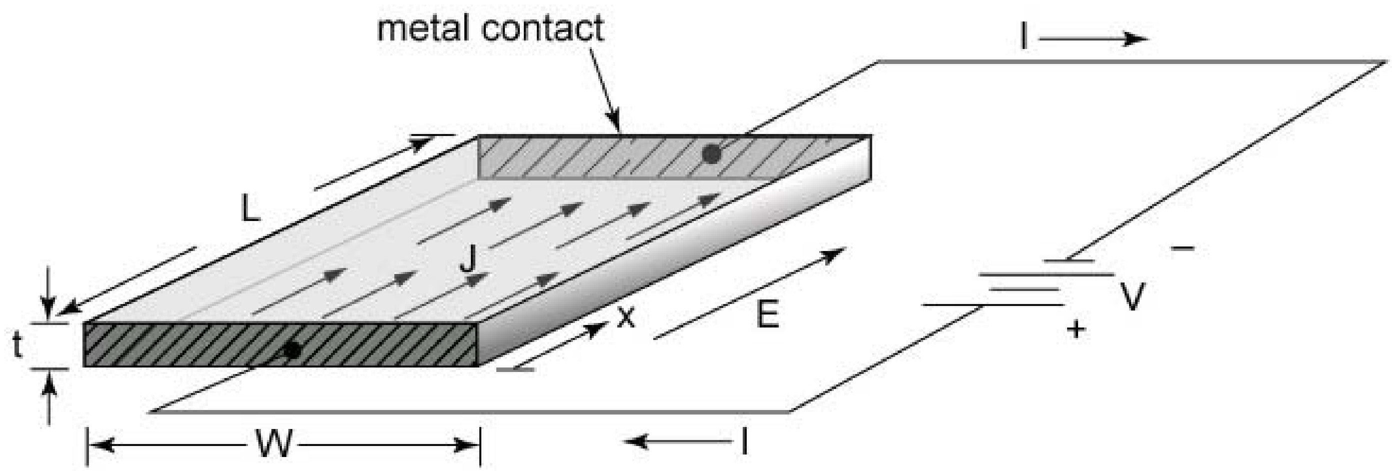
$$J_n = q\mu_n n E = \underbrace{q\mu_n N_d}E$$

Conductivity $\sigma_n =$

Resistivity $\rho_n =$

Ohm's Law

- Current I in terms of J_n
- Voltage V in terms of electric field



– Result for R

Sheet Resistance

- IC resistors have a specified thickness – not under the control of the *circuit* designer
- Eliminate t by absorbing it into a new parameter: the *sheet resistance*

$$R = \frac{\rho L}{Wt} = \left(\frac{\rho}{t}\right)\left(\frac{L}{W}\right) = R_{sq}\left(\frac{L}{W}\right)$$

$$\uparrow$$