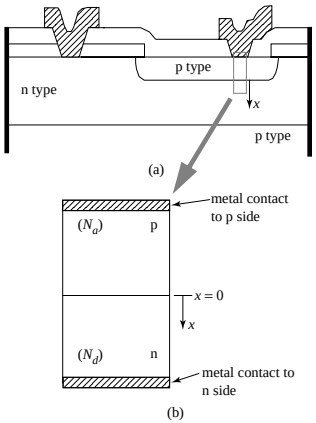
pn Junctions

- ubiquitous IC structure -- pn junctions are everywhere!



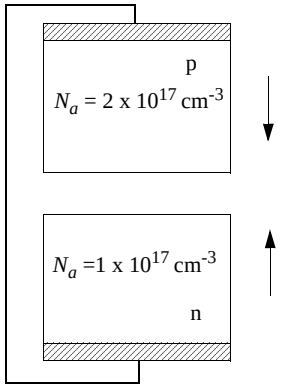
- thermal equilibrium: no hole current, no electron current ... no voltage applied between metal interconnects (could short them together)

Thermal Equilibrium

- Thought experiment: bring p and n Si blocks together

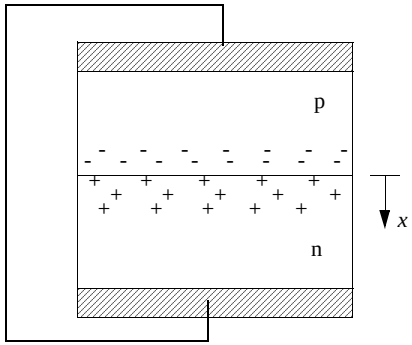
  holes flood from p side to n side of junction and electrons go the other way

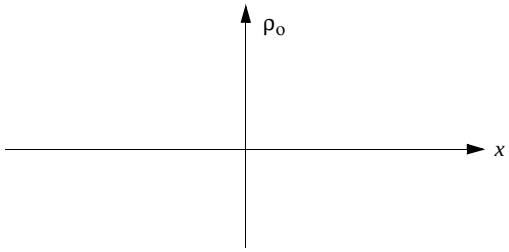
- what can balance out this transport and prevent the p & n sides from mixing?



Charge in pn Junction in Thermal Equilibrium

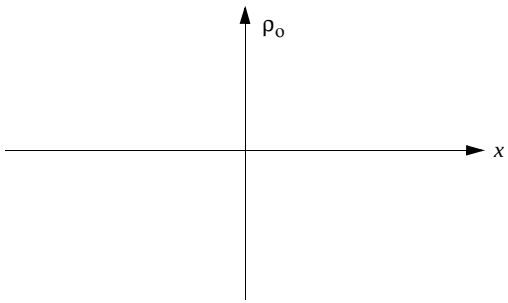
- Answer: a charged region at the junction!

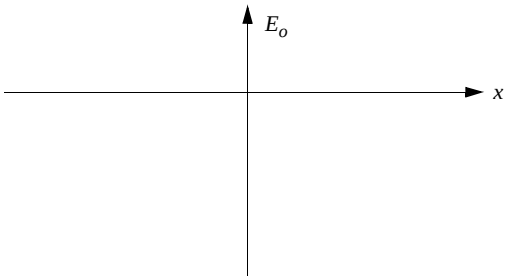




Qualitative Electrostatics in Equilibrium

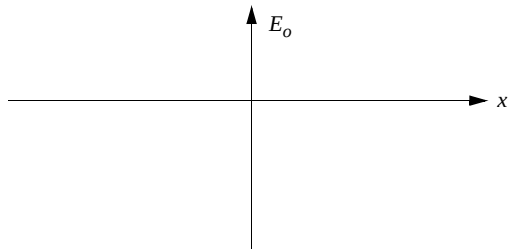
- From the charge density, we can find the electric field and the potential

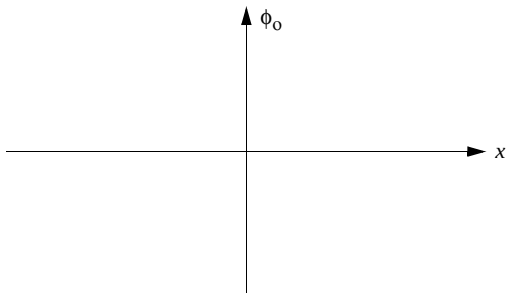




Qualitative Electrostatics in Equilibrium

- From the charge density, we can find the electric field and the potential





The Barrier Potential Across the Junction

- The n-side is at a higher potential that the p-side of the junction in thermal equilibrium (no applied voltage), due to the charged layer (called the depletion region) and the built-in field

- To quantify the potential $\phi_o(x)$, we need to pick a reference where $\phi_o = 0$

  Conventional choice: *intrinsic* (pure/compensated) silicon --> $\phi_o = 0$

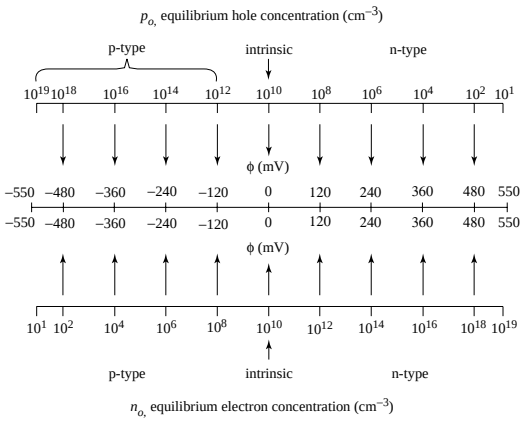
  n-type silicon in thermal equilibrium (subscript is "o")

$$\boxed{\phi_o = V_{th}\ln\left(\frac{n_o}{n_i}\right) = (26\text{mV})\ln(10)\log\left(\frac{n_o}{10^{10}}\right) = (60\text{mV})\log\left(\frac{n_o}{10^{10}}\right)}$$

  p-type silicon in thermal equilibrium

$$\boxed{\phi_o = V_{th}\ln\left(\frac{n_i}{p_o}\right) = (-26\text{mV})\ln(10)\log\left(\frac{p_o}{10^{10}}\right) = (-60\text{mV})\log\left(\frac{p_o}{10^{10}}\right)}$$

The 60 mV Rule



Examples:

Measuring the Built-In Potential Barrier

- Can ϕ_B be measured externally?