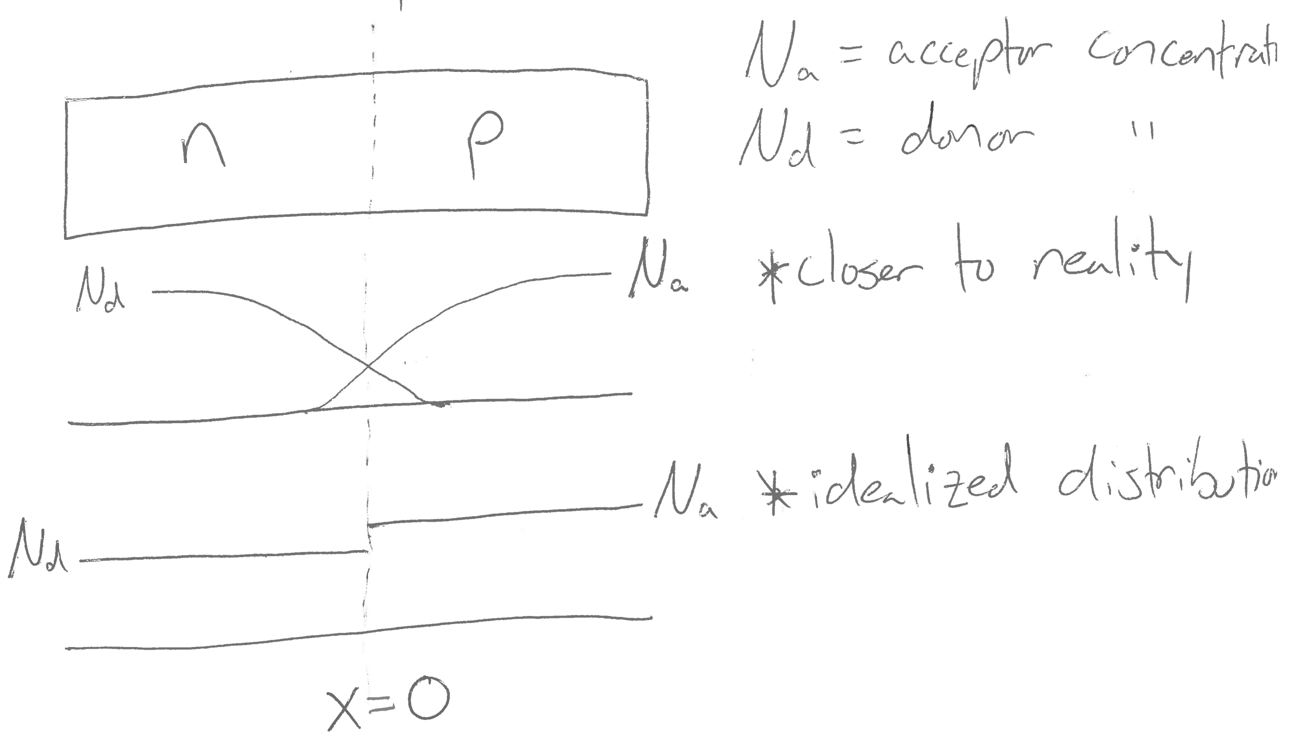
Mon. Nov. 26

- We have been discussing doping semiconductors in order to increase the conductivity of intrinsic semiconducting materials
- Recall:

  n-doped → e^- donor, e.g. P in Si
  p-doped → e^- acceptor, e.g. Al in Si

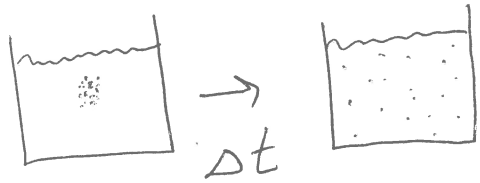
- it is important to note doped semiconductors remain electrically neutral
- let's see what happens when we form a junction between a p- + n-type semicond.

N_a = acceptor concentrati
N_d = donor "



- What happens when we bring two doped semicond. to form a "p-n junction"

- recall: diffusion → movement of particles from volume of high concentration to low



- phenomenological approach: Fick's laws of diff.

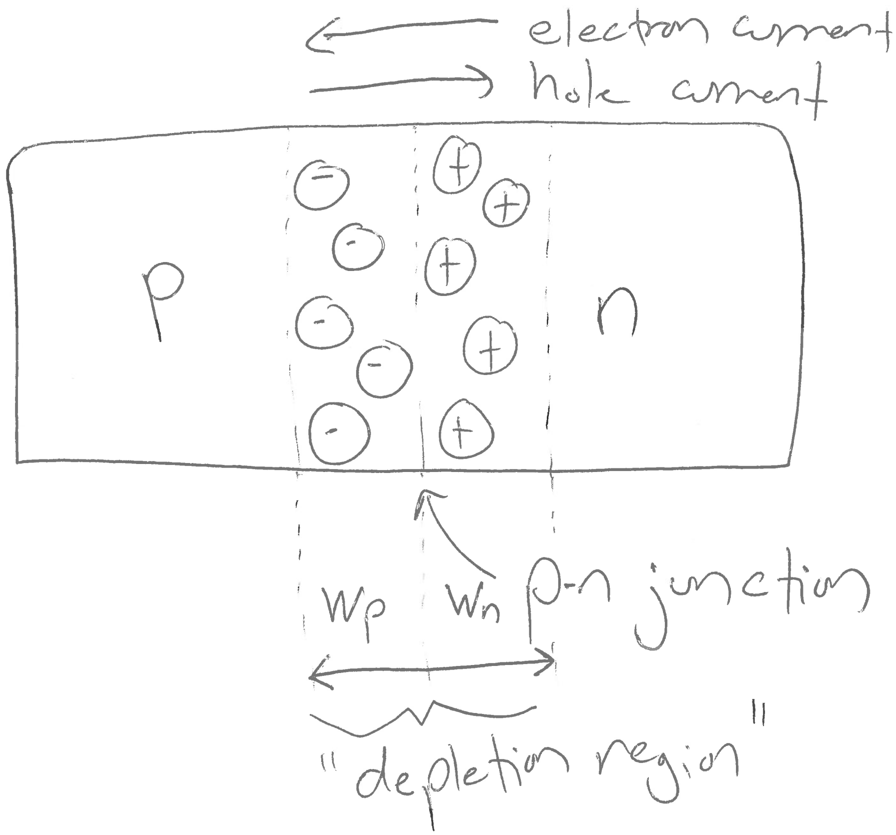
  @ steady state: $\vec{J} = -D \nabla \phi$, $D \equiv$ diff. coeff. (m^2/s)

  $\vec{J} \equiv$ flux of a substance $\left(\frac{\#}{area} \frac{1}{t}\right)$

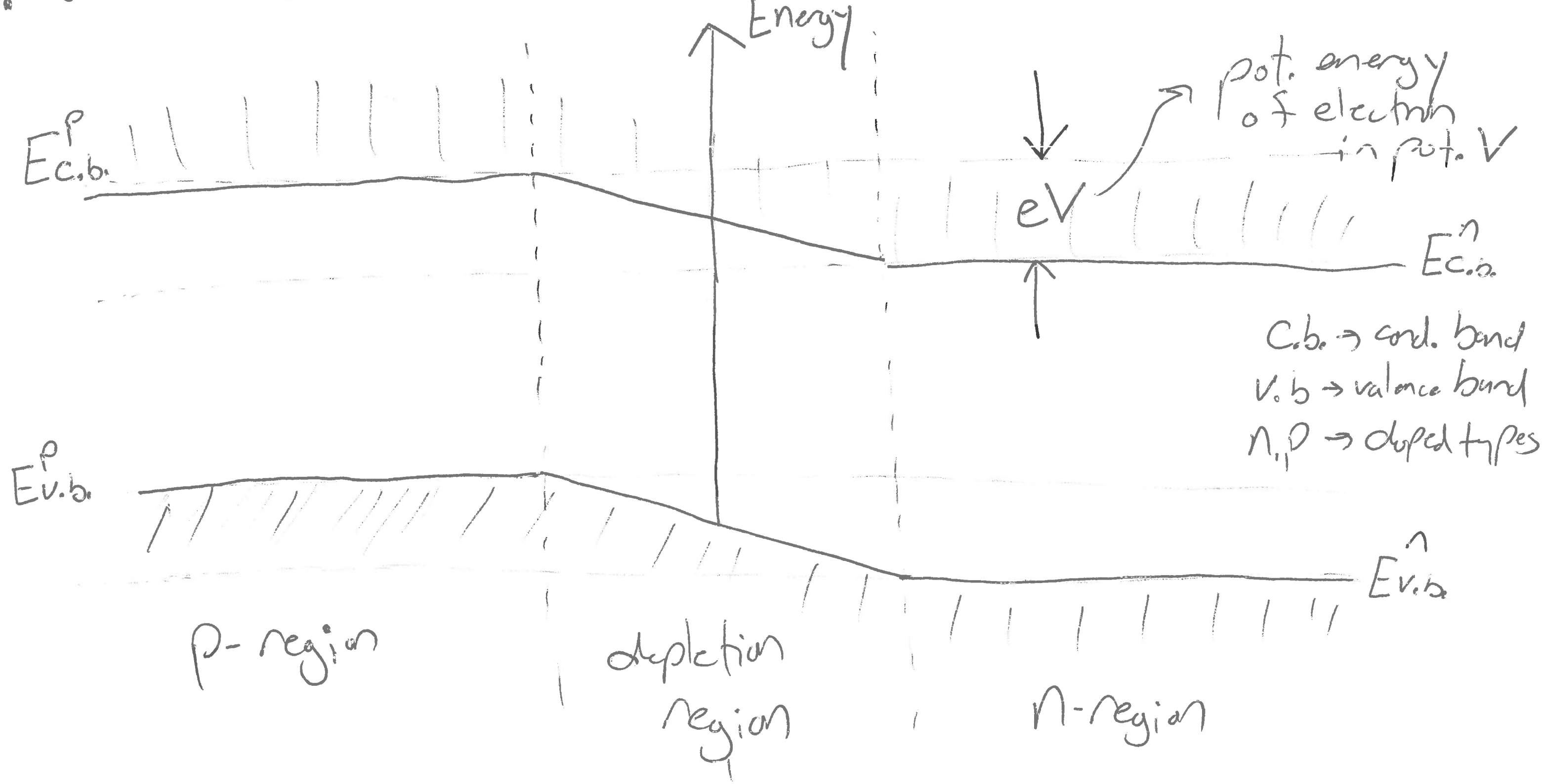
  $\phi \equiv$ concentration (mol/m^3)

- for the p-n junction we find unequal concentrations of e^- + e^+

- thus, we expect holes to diffuse into the n-region + electrons into p-region



- We find that the two diffusion currents build up an electric potential (E-field also) even though both materials are neutral
- What does the band structure look like?



- the energy difference in the c.b. is

$$E_{c.b.}^{p} - E_{c.b.}^{n} = eV, \text{ where}$$

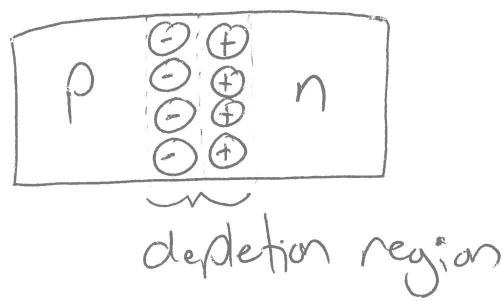
$e \equiv$ electron charge + $V \equiv$ electric potential

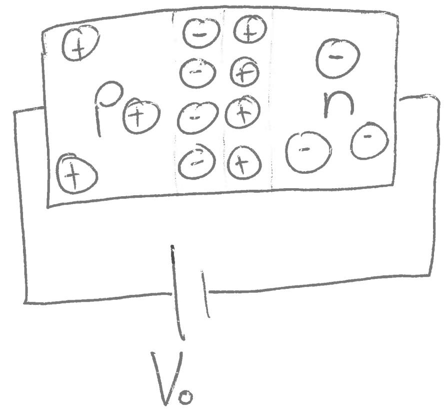
- note that the energy of electrons is higher on p-side due to higher concentration of electrons

- so perhaps this is an intellectual curiosity, but why do we care?

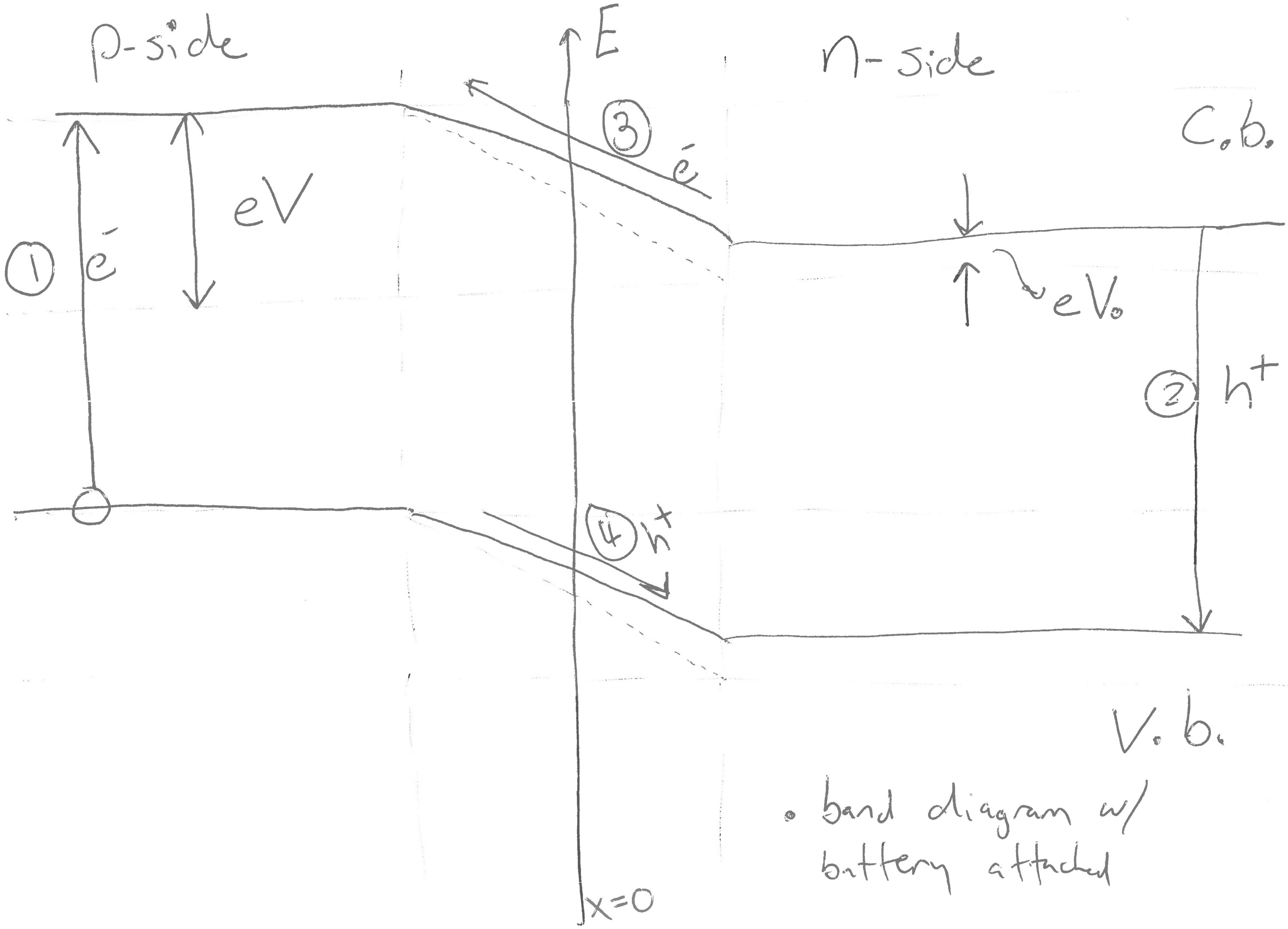
- first, imagine a solar cell: a photon with energy above E_g, an electron-hole pair is formed, but most recombine
- with a p-n junction, the electric "contact" potential causes the electrons (excited by photons) to be "swept" toward the n-region + vice versa. This current can be used to do work (electrical current)

- let's connect a battery to our p-n junction





- battery is wired in "forward bias" configuration



- band diagram w/ battery attached

(1) electrons are thermally excited into c.b. on the p-side

(2) holes are thermally excited down on n-side

excitations leads to

$$I_{left} \propto e^{-E_{gap}/k_B T}$$

(3) electrons can stay in v.b. but move from n- to p-side (also thermal)

(4) similar process for holes

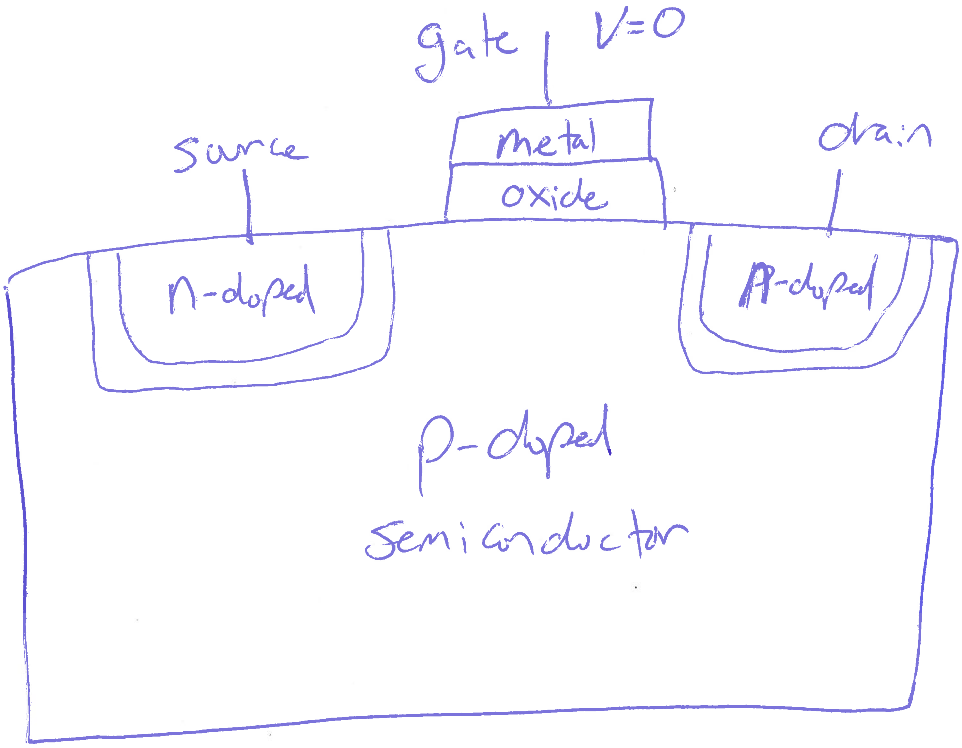
- processes (3) + (4) depend upon V_0, applied voltage

- we can show $\dfrac{I_{bias}}{I_{no,bias}} \propto e^{eV_0/k_B T}$

- current flows easily to p-side + not very well in opposite direction

- the transistor:

- no gate voltage



- gate voltage $V > V_{threshold}$