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Microelectronics HW5

Reading list: Chapter 5 (pages 195 - 223. Ignore section 5.2.5).

1. (Problem 5.4 in text) A Si step junction under equilibrium at 300 K has a p-side doping of NA = 2 × 10^15 cm^-3 and n-side doping of ND = 10^15 cm^-3. Calculate:
    a. The contact potential (also called built-in voltage).

V_bi=kt/q * ln(NA*ND/(ni^2))
V_bi=0.6132V

    b. The depletion layer width at the p-side and n-sides, and the total depletion layer width.

xn=((2 K_S e0 / q)(NA/(NA(NA+ND)))Vbi)^(1/2)
xn=7.3002*10^-5 cm
NA xp = ND xn
xp = xn / 2
xp = 3.6501*10^-5 cm
W=xn+xp
W=1.0950 * 10^-4 cm

    c. The electric field at the metallurgical junction.

Solved from part e.
E=-1.1198*10^4 V/cm

    d. The potential at the metallurgical junction.

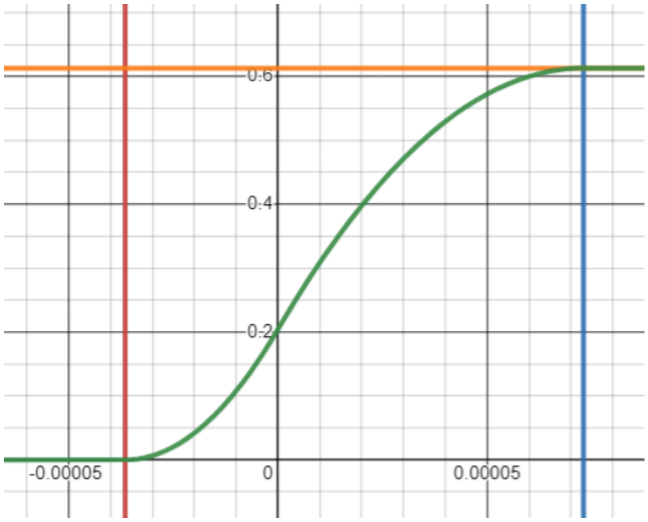
V=

{x < -xp	0
{-xp < x < 0	q NA / (2 KS e0) * (xp + x)^2
{x = 0	Vbi * ND / (NA + ND)
{0 < x < xn	Vbi - q ND / (2 KS e0) * (xn - x)^2
{ xn < x	Vbi

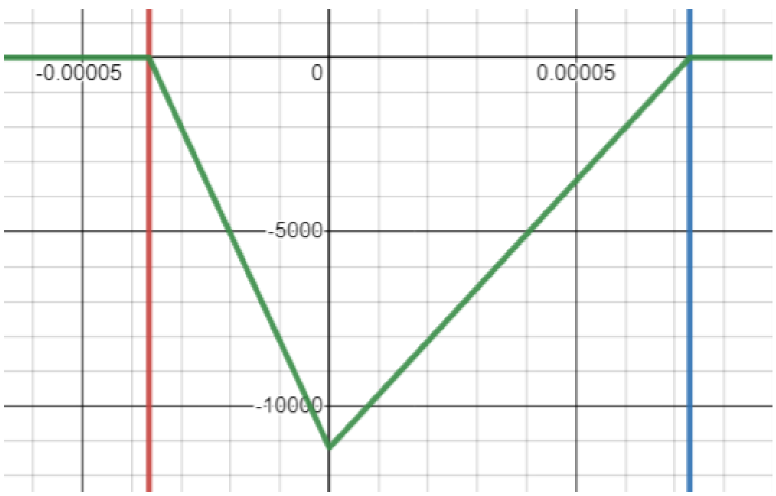
V(0) = Vbi * ND / (NA + ND) = 1/3 Vbi = 0.2044V

e. Make sketches of the charge density, electric field and electrostatic potential as a function of position, that are roughly to scale

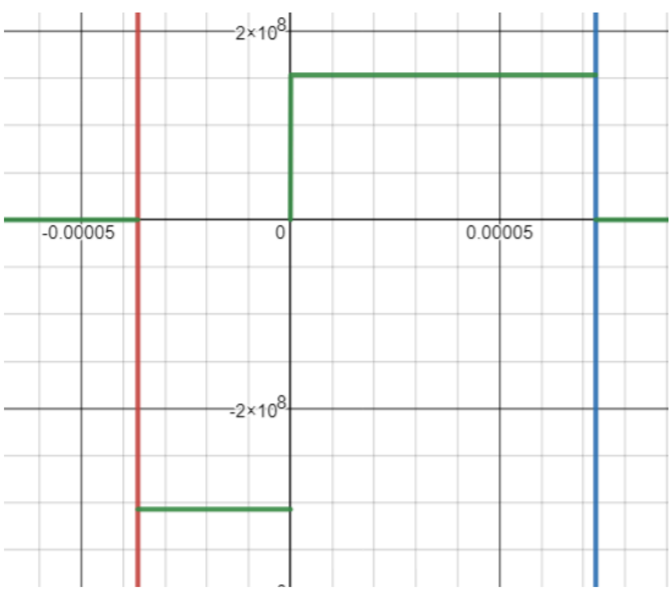
V(x)=



E(x)=dV/dx=

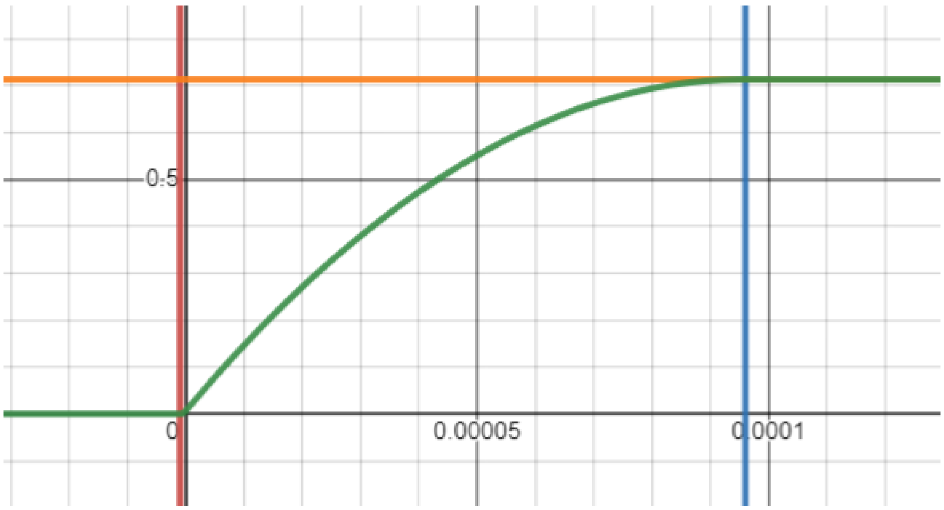


rho(x)=dE/dx=

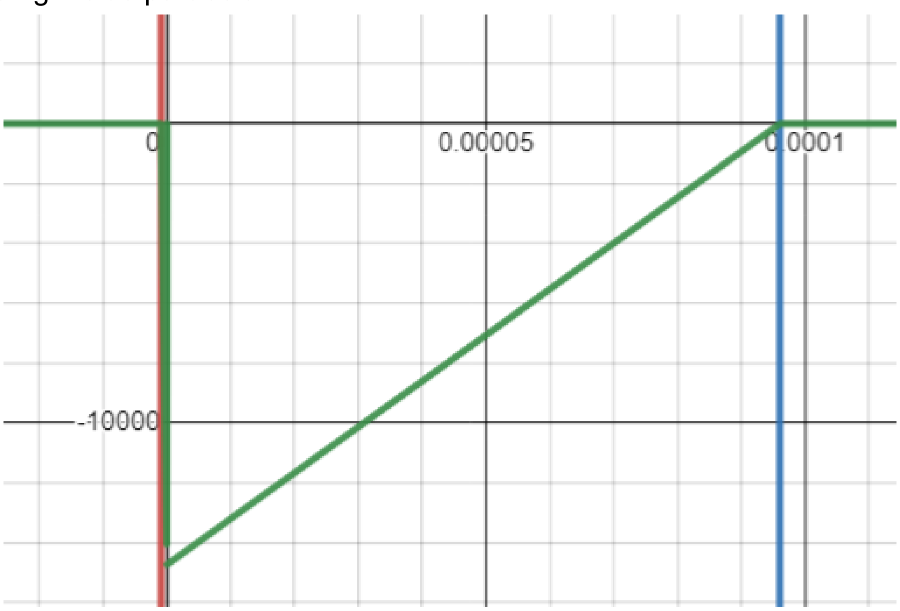


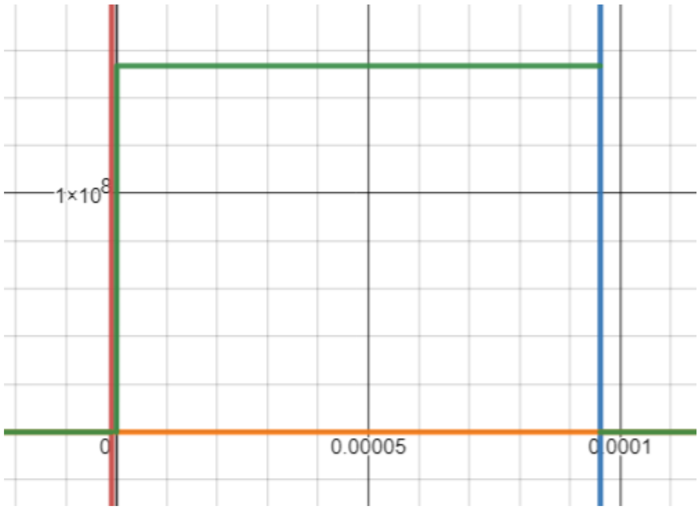
2. (Problem 5.5 in text) Repeat problem 1 taking NA = 10^17cm^-3 to be the p-side doping. Briefly compare the results here with those obtained in problem 1.

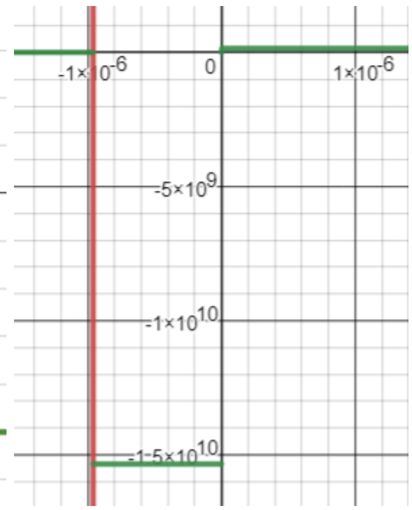
V_bi=0.7143V
xn=9.6022*10^-5 cm
xp=9.6022*10^-7 cm
W=9.6983*10^-5 cm
E=1.4730*10^4 V/cm
V(0) = Vbi * 10^15 / (10^15 + 10^17) = 7.0722*10^-3 V

V(x)= 

Vbi increased .61 to .71. xn xp shifted right and the gap shrank a little. The shape is dominated by the right side parabola.

E(x)= 

E(0) increased 11k to 14k. Again, the right side shape dominates rho(x)= 



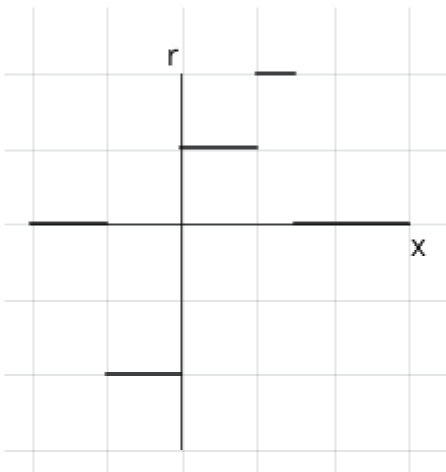
Charge density on the right is the same, but for a longer distance. Charge density on the left is a distance orders of magnitude shorter, and has a value orders of magnitude larger.

3. (Problem 5.10 in text). A p-n junction diode has the doping profile sketched below. Make the assumption that xn > x0 for all applied bias of interest. Answer the following:
   a. What is the built-in voltage across the junction? Justify your answer.

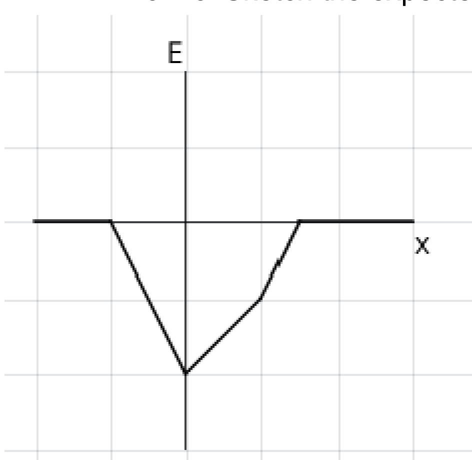
V_bi=kt/q * ln(NA*ND/(ni^2))

Voltage doesn’t care about path or distance, so the intermediate region has no effect on Vbi

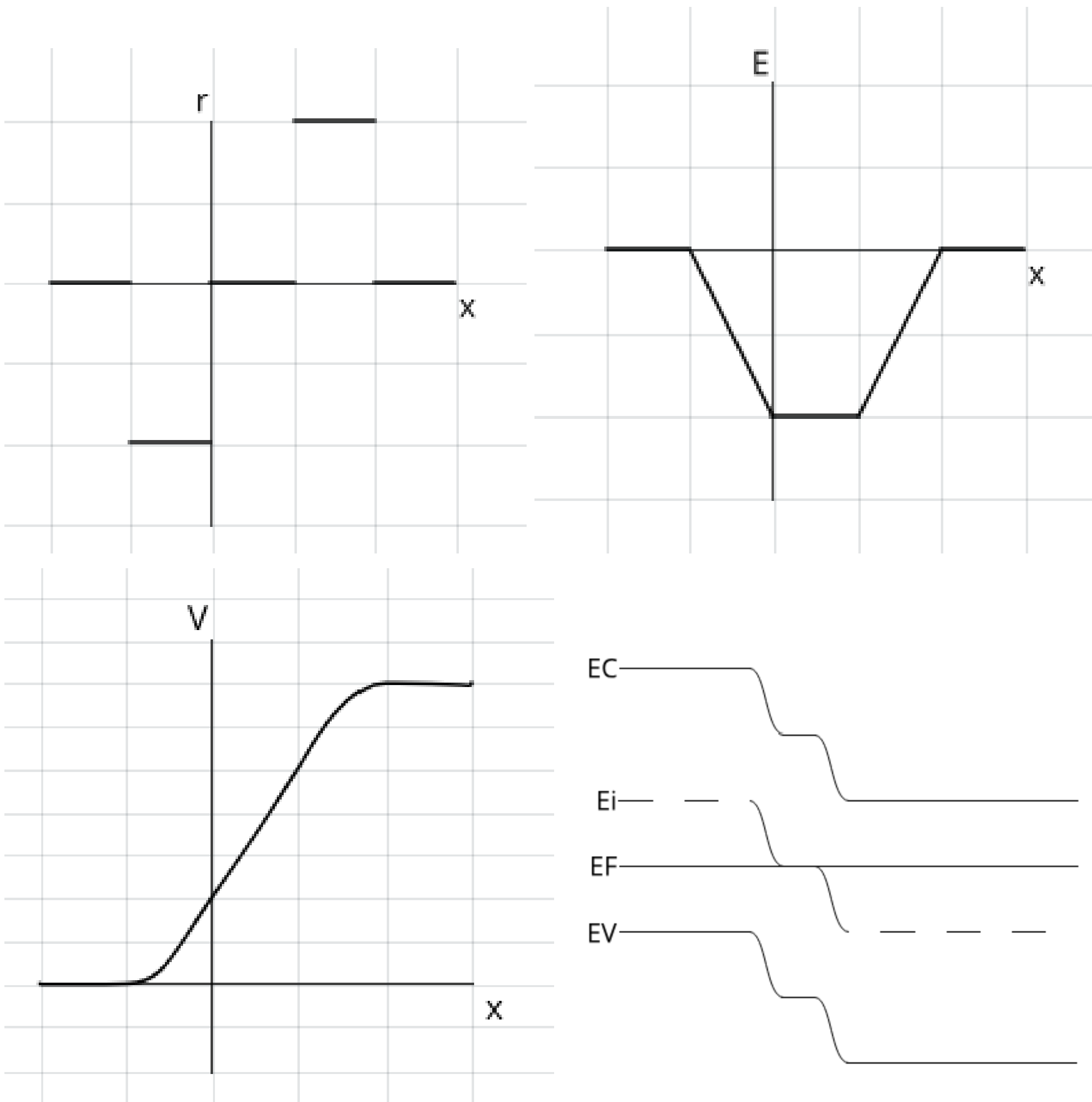
   b. Sketch the charge density r versus x inside the diode



   c. c. Sketch the expected electric field as a function of x inside the diode.



4. The p-i-n diode shown above is a three-region device with the middle region that is intrinsic and relatively narrow. Assuming the p- and n-regions to be uniformly doped and ND-NA = 0 in the i-region:
    a. Roughly sketch the expected charge density, electric field, and electrostatic potential inside the device. Also, draw the energy band diagram for the device under thermal equilibrium conditions.



    b. What is the built-in voltage drop between the p- and n-regions? Show how you arrived with your answer.

Again, voltage doesn't care about path or distance or what's in between, the intrinsic region has no effect.
Vbi=kT/q * ln(NA*ND/ni^2)
Vbi=.025 * ln(NA*ND*10^-20)