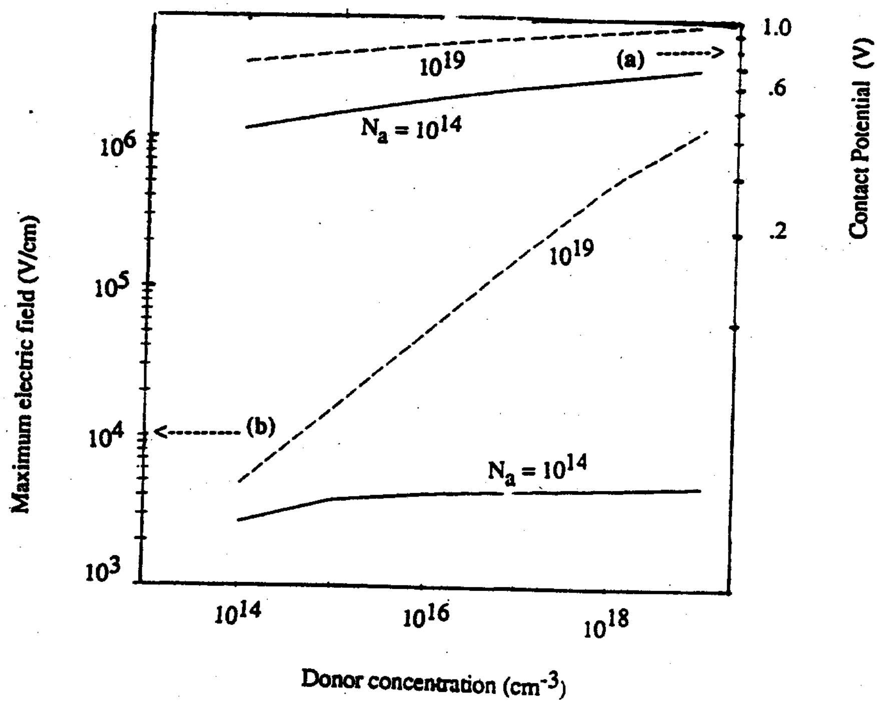
Prob. 5.7

a) Calculate contact potential V_0, in a Si p-n junction at 300 K.

$$V_0 = \frac{kT}{q} \ln \frac{N_a N_d}{n_i^2}$$

$$V_0 = 0.0259 \ln \frac{N_a N_d}{(1.5 \cdot 10^{10})^2}$$

b) Plot E_0 vs. N_d



Prob. 5.8

Find the electron diffusion and drift currents at x_n in a p^+-n junction.

$$I_p(x_n) = q \cdot A \cdot \frac{D_p}{L_p} \cdot p_n \cdot e^{\frac{q \cdot V}{kT}} \cdot e^{-\frac{x_n}{L_p}} \text{ for } V \gg \frac{kT}{q}$$

$$I = I_p(x_n = 0) = q \cdot A \cdot \frac{D_p}{L_p} \cdot p_n \cdot e^{\frac{q \cdot V}{kT}}$$

Assuming space charge neutrality, the excess hole distribution is equal to the excess electron distribution $\delta n(x_n) = \delta p(x_n)$

$$I_n(x_n)_{diff} = q \cdot A \cdot D_n \cdot \frac{d\delta p}{dx_n} = -q \cdot A \cdot \frac{D_n}{L_p} \cdot p_n \cdot e^{\frac{q \cdot V}{kT}} \cdot e^{-\frac{x_n}{L_p}}$$

$$I_n(x_n)_{drift} = I - I_n(x_n)_{diff} - I_p(x_n) = q \cdot A \cdot \frac{p_n}{L_p} \cdot \left[D_n \cdot \left(1 - e^{-\frac{x_n}{L_p}}\right) + D_n \cdot e^{-\frac{x_n}{L_p}} \right] \cdot e^{\frac{q \cdot V}{kT}}$$

Prob. 5.9

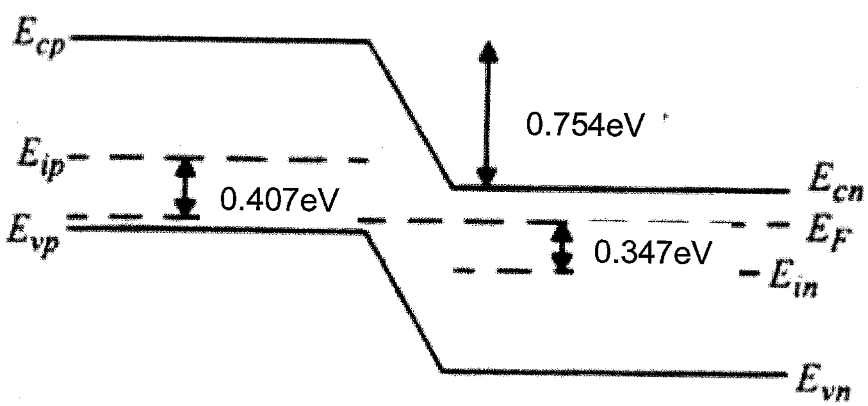
A Si junction has $N_a = 10^{17} \frac{1}{cm^3}$ and $N_d = 10^{16} \frac{1}{cm^3}$. Find (a)$E_F$, V_o, and band diagram and (b) compare this value of V_o to that from Equation 5-8.

(a)

$$E_{ip} - E_F = kT \cdot \ln \frac{p_p}{n_i} = 0.0259\text{eV} \cdot \ln \frac{10^{17} \frac{1}{cm^3}}{1.5 \cdot 10^{10} \frac{1}{cm^3}} = 0.407\text{eV}$$

$$E_F - E_{in} = kT \cdot \ln \frac{n_n}{n_i} = 0.0259\text{eV} \cdot \ln \frac{10^{16} \frac{1}{cm^3}}{1.5 \cdot 10^{10} \frac{1}{cm^3}} = 0.347\text{eV}$$

$$q \cdot V_o = 0.407\text{eV} + 0.347\text{eV} = 0.754\text{eV}$$



(b) $$q \cdot V_o = kT \cdot \ln \frac{N_a N_d}{n_i^2} = 0.0259\text{eV} \cdot \ln \frac{10^{17} \frac{1}{cm^3} \cdot 10^{16} \frac{1}{cm^3}}{\left(1.5 \cdot 10^{10} \frac{1}{cm^3}\right)^2} = 0.754\text{eV}$$

Prob. 5.10

Find V_0, x_{n0}, x_{p0}, Q_+, and $\mathcal{E}_o$ in Si at 300 K.

$$V_0 = \frac{kT}{q} \ln \frac{N_a N_d}{n_i^2}$$

$$V_0 = 0.0259\text{V} \ln \frac{4 \cdot 10^{18} \frac{1}{\text{cm}^3} \cdot 10^{16} \frac{1}{\text{cm}^3}}{(1.5 \cdot 10^{10} \frac{1}{\text{cm}^3})^2}$$

$$V_0 = 0.8498 \text{ V}$$

$$W = \sqrt{\frac{2 \epsilon_{Si} V_0}{q} \left(\frac{1}{N_a} + \frac{1}{N_d} \right)}$$

$$W = 0.334 \ \mu\text{m}$$

$$x_{n0} = \frac{W}{1 + \frac{N_d}{N_a}} = 0.333 \ \mu\text{m}$$

$$x_{p0} = \frac{W}{1 + \frac{N_a}{N_d}} = 0.83 \text{ nm}$$

$$Q_+ = -Q_- = q A x_{n0} N_d = 0.107 \text{ nC}$$

$$\mathcal{E}_0 = \frac{-q N_d x_{n0}}{\epsilon_{Si}} = -5.1 \cdot 10^4 \text{ V/cm}$$

Prob. 5.11

Describe the effect on the hole diffusion current of doubling the p^+ doping.

The depletion edge and electron diffusion current on the p^+ side may be ignored and

$$L_p = \sqrt{D_p \cdot \tau_p} = \sqrt{20\tfrac{cm^2}{s} \cdot 50 \cdot 10^{-9}s} = 10^{-3}cm = 10\mu m$$

$$\delta p = \frac{n_i^2}{N_d} \cdot \left(e^{\frac{qV}{kT}} - 1 \right) \cdot e^{-\frac{x}{L_p}}$$

$$\frac{d(\delta p)}{dx} = -\frac{1}{L_p} \cdot \frac{n_i^2}{N_d} \cdot \left(e^{\frac{qV}{kT}} - 1 \right) \cdot e^{-\frac{x}{L_p}} = -\frac{1}{10^{-3}cm} \cdot \frac{\left(10^{10}\frac{1}{cm^3}\right)^2}{10^{16}\frac{1}{cm^3}} \cdot \left(e^{\frac{0.6}{0.026}} - 1 \right) \cdot e^{-\frac{2\mu m}{10\mu m}} = -8.6 \cdot 10^{16} \frac{1}{cm^4}$$

$$J_p(\text{diffusion}) = -q \cdot D_p \cdot \frac{d(\delta p)}{dx} = 1.609 \cdot 10^{-19}C \cdot 20\tfrac{cm^2}{s} \cdot 8.6 \cdot 10^{16}\frac{1}{cm^4} = 0.277\frac{A}{cm^2}$$

Since this is independent of the p^+ doping, there will be no change.

Prob. 5.12

For the Si p^+-n junction, find I for V_f=0.5V.

$$I = q \cdot A \cdot \frac{D_p}{L_p} \cdot p_n \cdot e^{\frac{q \cdot V}{kT}} = q \cdot A \cdot \frac{D_p}{\sqrt{D_p \cdot \tau_p}} \cdot \frac{n_i^2}{n_n} \cdot e^{\frac{q \cdot V}{kT}}$$

$$I = 1.6 \cdot 10^{-19}C \cdot 10^{-3}cm^2 \cdot \frac{10\frac{cm^2}{s}}{\sqrt{10\frac{cm^2}{s} \cdot 10^{-6}s}} \cdot \frac{(1.5 \cdot 10^{10}\frac{1}{cm^3})^2}{5 \cdot 10^{16}\frac{1}{cm^3}} \cdot e^{\frac{0.5eV}{0.0259eV}} = 0.55\mu A$$