EECS170A ELECTRONICS I

Week 6 Discussion class: Examples for calculations of X_p, X_n, V_{bi}

Example 1: Problem 5.4 from textbook on page 228

A Si step junction maintained at room temperature under equilibrium conditions has a p-side doping of $N_A = 2 \times 10^{15}/cm^3$ and an n-side doping of $N_D = 10^{15}/cm^3$.

a) Compute V_{bi}.

Using equation 5.10 from page 204:

$$V_{bi} = (kT/q) \ln(N_A N_D / n_i^2)$$
$$= (0.0259) \ln [(2 \times 10^{15}) \times (10^{15}) / (10^{10})^2]$$
$$= 0.614 \text{ V}$$

b) Compute x_p, x_n and W.

Using equation 5.30 a and 5.30b from page 214:

$$x_p = [(2K_S\varepsilon_0 / q) . (N_D/ (N_A (N_A+N_D))) . V_{bi}]$$
$$= [(2 \times 11.8 \times 8.85 \times 10^{-14}/1.6 \times 10^{-19}) \times (10^{15}/ (2 \times 10^{15} \times (2 \times 10^{15} + 10^{15}) \times 0.614)$$
$$= 3.66 \times 10^{-5} \text{ cm.}$$

$$x_n = [(2K_S\varepsilon_0 / q) . (N_A/ (N_D (N_A+N_D))) . V_{bi}]$$
$$= [(2 \times 11.8 \times 8.85 \times 10^{-14}/1.6 \times 10^{-19}) \times (2 \times 10^{15}/ (10^{15} \times (2 \times 10^{15} + 10^{15}) \times 0.614)$$
$$= 7.31 \times 10^{-5} \text{ cm.}$$

$$W = x_n + x_p = 3.66 \times 10^{-5} + 7.31 \times 10^{-5} = 10.97 \times 10^{-5} \text{ cm.}$$

c) Compute ε at x = 0.

Using equation 5.35 from page 216:

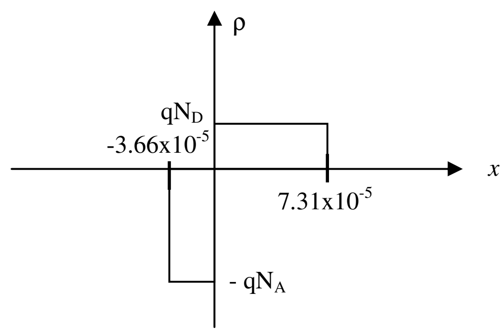
$$\varepsilon (0) = - qN_D x_n / K_S\varepsilon_0$$
$$= - [(1.6 \times 10^{-19}) \times (10^{15}) \times (7.31 \times 10^{-5})] / [(11.8) \times (8.85 \times 10^{-14})]$$
$$= - 1.12 \times 10^4 \text{ V/cm}$$

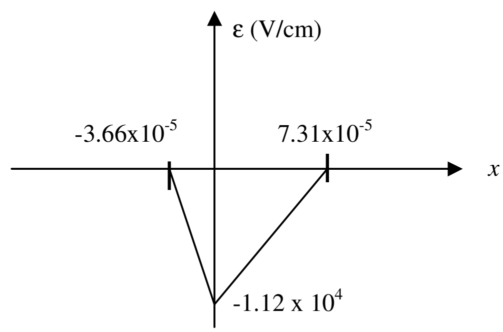
d) Compute V at x = 0.

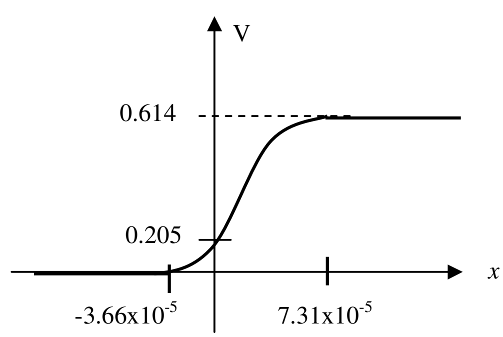
Using equation 5.33 from page 216:

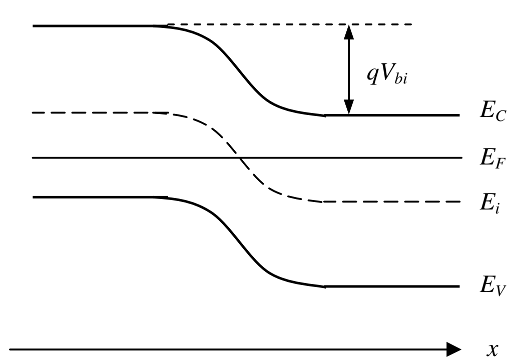
$$V (0) = qN_A x_P^2 / 2K_S\varepsilon_0$$
$$= [(1.6 \times 10^{-19}) \times (2 \times 10^{15}) \times (3.66 \times 10^{-5})^2] / [2 \times (11.8) \times (8.85 \times 10^{-14})]$$
$$= 0.205 \text{ V.}$$

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









Example 2: Problem 5.5 from textbook on page 229

Repeat Problem 5.4, taking $N_A = 10^{17}/cm^3$ to be the p-side doping. Briefly compare the results here with those of Problem 5.4.

a) Compute V_{bi}.

Using equation 5.10 from page 204:

$V_{bi} = (kT/q)\ ln(N_A N_D / n_i^2)$

$= (0.0259)\ ln\ [(10^{17}) \times (10^{15}) / (10^{10})^2]$

$= 0.716$ V

b) Compute x_p, x_n and W.

Using equation 5.30 a and 5.30b from page 214:

$x_p = [(2K_S\varepsilon_0 / q) . (N_D/ (N_A (N_A+N_D))) . V_{bi}]$

$= [(2 \times 11.8 \times 8.85 \times 10^{-14}/1.6 \times 10^{-19}) \times (10^{15}/ (10^{17} \times (10^{17} + 10^{15}) \times 0.716))$

$= 9.62 \times 10^{-7}$ cm.

$x_n = [(2K_S\varepsilon_0 / q) . (N_A/ (N_D (N_A+N_D))) . V_{bi}]$

$= [(2 \times 11.8 \times 8.85 \times 10^{-14}/1.6 \times 10^{-19}) \times (10^{17}/ (10^{15} \times (10^{17} + 10^{15}) \times 0.716))$

$= 9.62 \times 10^{-5}$ cm.

$W = x_n + x_p = 9.62 \times 10^{-5} + 9.62 \times 10^{-7} = 9.72 \times 10^{-5}$ cm.

c) Compute ε at x = 0.

Using equation 5.35 from page 216:

$\varepsilon\ (0) = - qN_D x_n / K_S\varepsilon_0$

$= - [(1.6 \times 10^{-19}) \times (10^{15}) \times (9.62 \times 10^{-5})] / [(11.8) \times (8.85 \times 10^{-14})]$

$= - 1.47 \times 10^4$ V/cm

d) Compute V at x = 0.

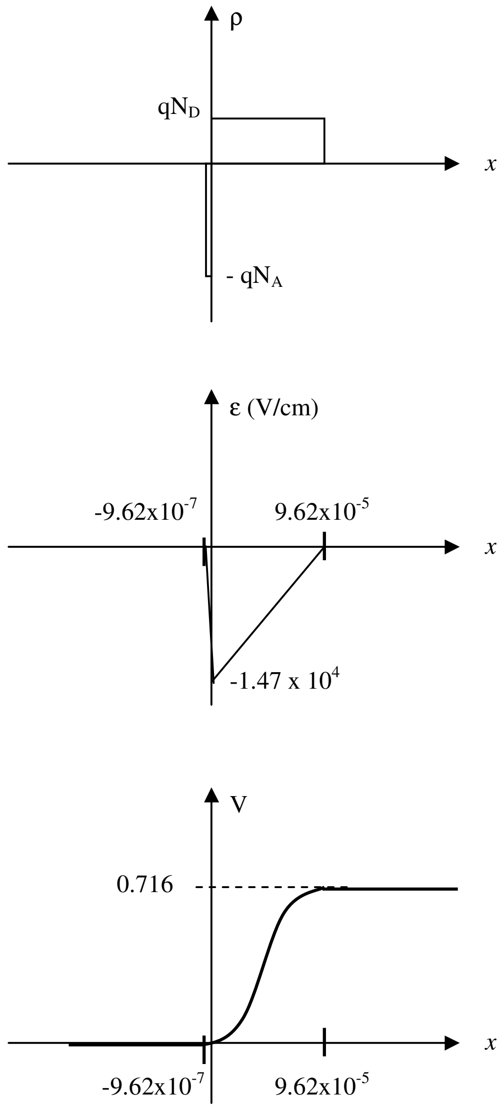
Using equation 5.33 from page 216:

$V\ (0) = qN_A x_P^2 / 2K_S\varepsilon_0$

$= [(1.6 \times 10^{-19}) \times (10^{15}) \times (9.62 \times 10^{-7})^2] / [\ 2 \times (11.8) \times (8.85 \times 10^{-14})]$

$= 7.09 \times 10^{-3}$ V.

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



In Problem 5.4, the widths of the n- and p-sides of the depletion region and the corresponding variation of the electrostatic variables are comparable reflecting the fact that $N_A \sim N_D$. Here with $N_A >> N_D$, the depletion width and potential drop lie almost exclusively on the lowly doped n-side of the junction.