EE 320 HOMEWORK 1, SOLUTION

3.1 Use the expression in Eq. (3.2), with

$B = 7.3 \times 10^{15}\ \text{cm}^{-3}\text{K}^{-3/2}$;

$k = 8.62 \times 10^{-5}\text{eV/K}$; and $E_g = 1.12\ \text{V}$

we have

$T = -55°\text{C} = 218\ \text{K}$:

$$n_i = 2.68 \times 10^{6}\ \text{cm}^{-3};\ \frac{N}{n_i} = 1.9 \times 10^{16}$$

That is, one out of every 1.9×10^{16} silicon atoms is ionized at this temperature.

$T = 0°\text{C} = 273\ \text{K}$:

$$n_i = 1.52 \times 10^{9}\ \text{cm}^{-3};\ \frac{N}{n_i} = 3.3 \times 10^{13}$$

$T = 20°\text{C} = 293\ \text{K}$:

$$n_i = 8.60 \times 10^{9}\ \text{cm}^{-3};\ \frac{N}{n_i} = 5.8 \times 10^{12}$$

$T = 75°\text{C} = 348\ \text{K}$:

$$n_i = 3.70 \times 10^{11}\ \text{cm}^{-3};\ \frac{N}{n_i} = 1.4 \times 10^{11}$$

$T = 125°\text{C} = 398\ \text{K}$:

$$n_i = 4.72 \times 10^{12}\ \text{cm}^{-3};\ \frac{N}{n_i} = 1.1 \times 10^{10}$$

3.2 Use Eq. (3.2) to find n_i,

$$n_i = BT^{3/2}\, e^{-E_g/2kT}$$

Substituting the values given in the problem,

$$n_i = 3.56 \times 10^{14}(300)^{3/2} e^{-1.42/(2\times 8.62\times 10^{-5}\times 300)}$$

$$= 2.2 \times 10^6 \text{ carriers/cm}^3$$

3.5 $T = 27°\text{C} = 273 + 27 = 300\text{ K}$

At 300 K, $n_i = 1.5 \times 10^{10}/\text{cm}^3$

Phosphorus-doped Si:

$n_n \simeq N_D = 10^{17}/\text{cm}^3$

$$p_n = \frac{n_i^2}{N_D} = \frac{(1.5 \times 10^{10})^2}{10^{17}} = 2.25 \times 10^3/\text{cm}^3$$

Hole concentration $= p_n = 2.25 \times 10^3/\text{cm}^3$

$T = 125°\text{C} = 273 + 125 = 398\text{ K}$

At 398 K, $n_i = BT^{3/2}e^{-E_g/2kT}$

$= 7.3 \times 10^{15} \times (398)^{3/2}e^{-1.12/(2\times 8.62\times 10^{-5}\times 398)}$

$= 4.72 \times 10^{12}/\text{cm}^3$

$$p_n = \frac{n_i^2}{N_D} = 2.23 \times 10^8/\text{cm}^3$$

At 398 K, hole concentration is

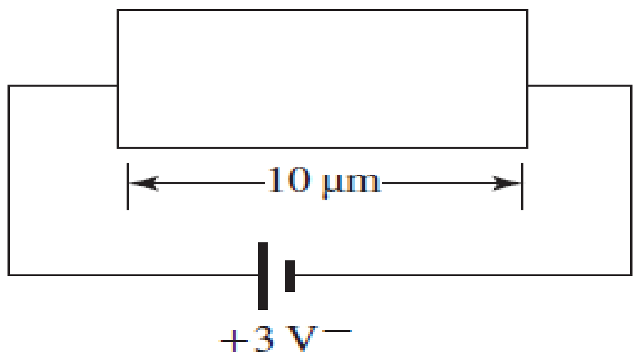
$p_n = 2.23 \times 10^8/\text{cm}^3$

3.7 Electric field:

$$E = \frac{3\ \text{V}}{10\ \mu\text{m}} = \frac{3\ \text{V}}{10 \times 10^{-6}\ \text{m}}$$

$$= \frac{3\ \text{V}}{10 \times 10^{-4}\ \text{cm}}$$

$$= 3000\ \text{V/cm}$$



$$\nu_{p\text{-drift}} = \mu_p E = 480 \times 3000$$

$$= 1.44 \times 10^6\ \text{cm/s}$$

$$\nu_{n\text{-drift}} = \mu_n E = 1350 \times 3000$$

$$= 4.05 \times 10^6\ \text{cm/s}$$

$$\frac{\nu_n}{\nu_p} = \frac{4.05 \times 10^6}{1.44 \times 10^6} = 2.8125 \quad \text{or}$$

$$\nu_n = 2.8125\ \nu_p$$

Or, alternatively, it can be shown as

$$\frac{\nu_n}{\nu_p} = \frac{\mu_n E}{\mu_p E} = \frac{\mu_n}{\mu_p} = \frac{1350}{480}$$

$$= 2.8125$$

3.10

$$p_{n0} = \frac{n_i^2}{N_D} = \frac{(1.5 \times 10^{10})^2}{10^{16}} = 2.25 \times 10^4/\text{cm}^3$$

From Fig. P3.10,

$$\frac{dp}{dx} = -\frac{10^8 p_{n0} - p_{n0}}{W} \simeq -\frac{10^8 p_{n0}}{50 \times 10^{-7}}$$

since 1 nm $= 10^{-7}$ cm

$$\frac{dp}{dx} = -\frac{10^8 \times 2.25 \times 10^4}{50 \times 10^{-7}}$$

$$= -4.5 \times 10^{17}$$

Hence

$$J_p = -qD_p \frac{dp}{dx}$$

$$= -1.6 \times 10^{-19} \times 12 \times (-4.5 \times 10^{17})$$

$$= 0.864 \text{ A/cm}^2$$