ECE 305 – Fall 2015

Solutions for Exam 1– Friday, September 18, 2015

Part I: Multiple Choice

1. D

The next-nearest neighbors are located on the face of the cube associated with the crystalline silicon lattice. Relative to the origin, these faces are located at $(\frac{a}{2}, \frac{a}{2}, 0)$ or similar. Thus, the total distance will be $a/\sqrt{2}$. Since $a = 5.43$ Å, we obtain a value of approximately 3.85 Å.

2. D

The key equation sheet indicates $J_n = nq\mu_n \mathcal{E}_x + qD_n \frac{dn}{dx}$. To eliminate drift effects, we set $\mathcal{E}_x = 0$, which leaves us with $J_n = +qD_n \frac{dn}{dx}$.

3. E

Carrier mobility is limited by at least two types of scattering: charged impurity scattering, which decreases with temperature; and lattice (phonon) scattering, which increases with temperature. The best tradeoff between these two is found at a finite temperature that depend on material properties such as dopant concentration, often (but not always) creating a mobility peak between 50 K and 200 K.

4. B

Taking the inverse of the intercepts yields $\left(\frac{1}{2}, 1, \frac{1}{3}\right)$. Multiplying each term by 6 yields the Miller index: (362).

5. B

The key equation sheet shows that $1/\rho = q\left(n\mu_n + p\mu_p\right)$. Since $N_D = 4.5 \times 10^{14}\ \mathrm{cm}^{-3}$, holes can be neglected, which implies $\rho \approx 1/(q\mu_n N_D)$. Plugging in the values provided ($\mu_n = 1400\ \mathrm{cm}^2$/V·s), we obtain $\rho \approx 10\ \Omega \cdot \mathrm{cm}$.

ECE 305 Exam I.

II. a. $p - n + N_D - N_A = 0.$

$$\Rightarrow p = \frac{1}{2}\left[N_A + \sqrt{N_A^2 + 4n_i^2}\right]$$

$$\simeq 1.01 \times 3\times10^{15}\ cm^{-3}$$

$$= 3.03 \times 10^{15}\ cm^{-3}$$

b. $$n = \frac{n_i^2}{p} = \frac{(3\times10^{14}\ cm^{-3})^2}{3.03\times10^{15}\ cm^{-3}} = 2.97 \times 10^{13}\ cm^{-3}.$$

c. $J_n = nq\mu_n E$

$J_p = pq\mu_p E$

$$E = \frac{V}{d} = \frac{1V}{250\times10^{-4}\ cm} = 40\ V/cm$$

$$J_n = 2.97\times10^{13}\ cm^{-3} \times 1.6\times10^{-19}\ C \times 8000\ cm^2/V\cdot s \times 40\ V/cm = 1.52\ A/cm^2$$

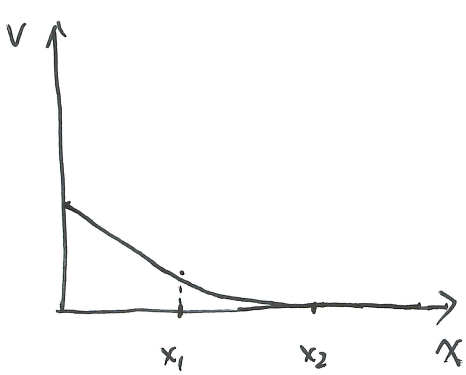
$$J_p = 3.03\times10^{15}\ cm^{-3} \times 1.6\times10^{-19}\ C \times 400\ cm^2/V\cdot s \times 40\ V/cm = 7.76\ A/cm^2$$

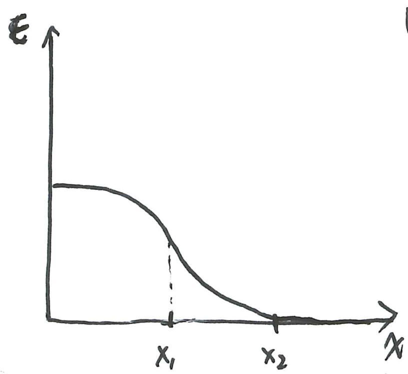
$$J_{drift} = J_n + J_p = 9.28\ A/cm^2$$

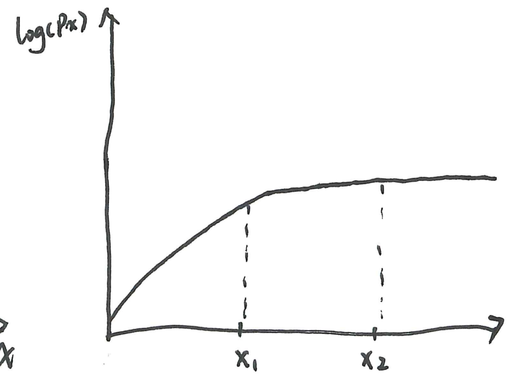
III. a. $$p = N_v e^{\frac{E_v - E_F}{kT}} = N_v e^{\frac{-E_g}{kT}} = 1.83\times10^{19}\ cm^{-3}\ e^{\frac{-1.12eV}{0.026eV}} \approx 3.58\ cm^{-3}$$

b. $E_F = E_i$, So $p = n_i\ \cancel{10^{10}\ cm^{-3}} = 1.1\times10^{10}\ cm^{-3}$

c. d e.







$V = \frac{E}{-q} + C$; $x \gg x_2, V=0$

$\mathcal{E} = -\frac{dV}{dx}$

$$\log[P(x)] = \frac{1}{2.3}\log(N_v) + \frac{1}{2.3}\frac{E_v - E_F}{kT}$$

$$\Rightarrow \log[P(x)] \propto E_v(x)$$