QUANTUM AND SOLID STATE PHYSICS : ASSIGNMENT 12

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Exercise 1.
A semiconductor is under constant illumination through a narrow opening. The illumination generates EHPs in the volume below the illuminated area. Given that in this semiconductor the diffusion coefficient of holes is larger than the diffusion coefficient of electrons, what will be the direction of the internal electric field at steady state?

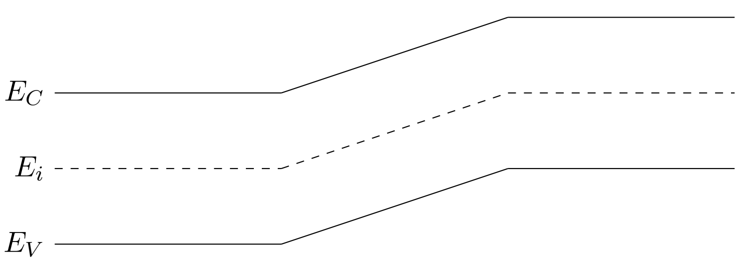
Solution 1.
As the diffusion coefficient of holes is larger than the diffusion coefficient of electrons, the mobility of holes is also larger than the mobility of electrons. Therefore, the holes diffuse more easily than the electrons. Hence, the curve of $\hat{p}(x)$ with respect to x, is wider than that of $\hat{n}(x)$.
Therefore, the internal electric field is directed inwards, towards the centre.

Exercise 2.
A silicon sample at equilibrium and at room temperature is doped N-type with a doping concentration profile as shown.

$N_{D1} = 10^{17} \frac{1}{\text{cm}^3}$	$N_{D2} = N_{D1} e^{-ax}$	$N_{D3} = 10^{15} \frac{1}{\text{cm}^3}$

$\longleftrightarrow$ 1µm (width of the middle region)

(1) Calculate the electric field $\overrightarrow{E}(x)$ in $\frac{\text{V}}{\text{cm}}$ in all three regions and plot $\overrightarrow{E}(x)$ with respect to x, across the entire sample.
(2) After calculating the electric field $\overrightarrow{E}(x)$ in all three regions, we expect to obtain an energy band diagram as shown.



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Draw the built-in voltage V_{BI} in the sample.

Solution 2.

(1) As the concentration profile is continuous at the interface of regions 2 and 3,

$$\begin{aligned}10^{17}e^{-a10^{-6}} &= 10^{15}\\ \therefore e^{-a10^{-6}} &= 10^{-2}\\ \therefore -a10^{-6} &= \ln\left(10^{-2}\right)\\ &= -2\ln(10)\\ \therefore a &= 2\ln(10)10^{6}\\ &= 4.6\times 10^{6}\end{aligned}$$

Therefore,

$$\begin{aligned}\overrightarrow{E}_1(x) &= -\frac{kT}{q}\frac{1}{N_{D1}}(x)\frac{\mathrm{d}N_d(x)}{\mathrm{d}x}\\ &= -\frac{kT}{q}\frac{1}{10^{17}}0\\ &= 0\end{aligned}$$

Therefore,

$$\begin{aligned}\overrightarrow{E}_2(x) &= -\frac{kT}{q}\frac{1}{N_{D2}}(x)\frac{\mathrm{d}N_d(x)}{\mathrm{d}x}\\ &= -\frac{kT}{q}\frac{1}{10^{17}e^{-ax}}\frac{\mathrm{d}10^{17}e^{-ax}}{\mathrm{d}x}\\ &= -\frac{kT}{q}\frac{1}{10^{17}e^{-ax}}\left(-a\times 10^{17}e^{-ax}\right)\\ &= \frac{kT}{q}a\end{aligned}$$

Therefore,

$$\begin{aligned}\overrightarrow{E}_3(x) &= -\frac{kT}{q}\frac{1}{N_{D3}}(x)\frac{\mathrm{d}N_d(x)}{\mathrm{d}x}\\ &= -\frac{kT}{q}\frac{1}{10^{15}}0\\ &= 0\end{aligned}$$

(2)