5.40 Consider an n-type semiconductor at $T = 300$ K in thermal equilibrium (no current). Assume that the donor concentration varies as $N_d(x) = N_{d0}e^{-x/L}$ over the range $0 \le x \le L$ where $N_{d0} = 10^{16}$ cm^{-3} and $L = 10$ μm. (*a*) Determine the electric field as a function of x for $0 \le x \le L$. (*b*) Calculate the potential difference between $x = 0$ and $x = L$ (with the potential at $x = 0$ being positive with respect to that at $x = L$).

a) Per (5.42), $E_x = -\left(\frac{k_B T}{e}\right)\frac{1}{N_d(x)}\frac{dN_d(x)}{dx}$. Using the given donor concentration $N_d(x)$ in MKS units, i.e., $N_d(x) = 10^{22}e^{-x/L}$ m^{-3}, we get

$$E_x = -\left(\frac{1.380649\times10^{-23}(300)}{1.602176634\times10^{-19}}\right)\frac{1}{10^{22}e^{-x/L}}\frac{d\,10^{22}e^{-x/L}}{dx}$$

$$= -2.5852\times10^{-2}e^{+x/L}e^{-x/L}\left(\frac{-1}{L}\right) = (1)\left(\frac{2.5852\times10^{-2}}{10\times10^{-6}}\right).$$

$\Rightarrow$ **E_x = 2585.2 V/m = 25.852 V/cm $0 \le x \le L$.**

b) By definition, $V = -\int \overline{E}\bullet d\overline{l}$. Therefore, the potential difference V is

$$V = -\int_{x=L}^{0} E_x\,dx = -\int_{x=L}^{0} 2585.2\,dx = -2585.2(0-L) = 2585.2(10\times10^{-6})$$

$\Rightarrow$ **V = 0.02585 V = 25.85 mV.**