4.4. (a) Use eq. (4–13) $g_{op} = \alpha_r (n_0 + p_0)\,\delta n = \dfrac{\delta n}{\tau_n}$

get $\alpha_r = \dfrac{1}{\tau_n (n_0 + p_0)}$ ...... (1)

$n_0 \approx N_d = 2\times10^{15}\ cm^{-3}$

$p_0 = \dfrac{n_i^2}{p_0} = \dfrac{(1.5\times10^{10})^2}{2\times10^{15}} \approx 10^5 \ll n_0$

So, $\boxed{\alpha_r \approx \dfrac{1}{\tau_n \cdot n_0} = \dfrac{1}{50\times10^{-9}s \times 2\times10^{15}cm^{-3}} = 10^{-8} cm^3/s}$

(b). $\Delta n = \Delta p = \tau_n \cdot g_{op} = 50\times10^{-9} s \times 10^{20}\ EHP/cm^3$

$\boxed{\Delta n = \Delta p = 5\times10^{12}\ cm^{-3}}$

4.13. (a) $N_a(x) = P_0 \cdot e^{-ax}$

From $J_p(x) = q\mu_p p(x)\,\mathcal{E}(x) - qD_p \dfrac{dp(x)}{dx} = 0$

$p(x) \approx N_a(x) = P_0 e^{-ax}$

$\mathcal{E}(x) = -\dfrac{kT}{q} a < 0$

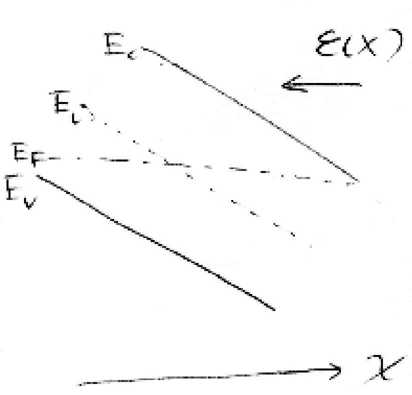
$\therefore \dfrac{d\varphi}{dx} = -\mathcal{E}(x) > 0$

(b). P-doping $N_d(x) = n_0 \exp(-ax)$

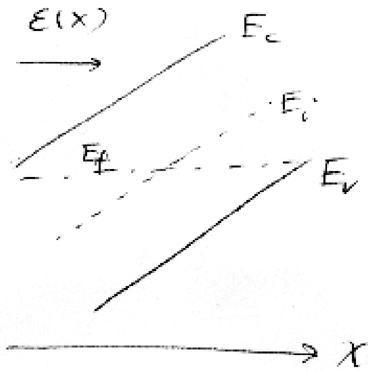
From $J_n(x) = q\mu_n n(x)\,\mathcal{E}(x) + qD_n \dfrac{dn(x)}{dx} = 0$

$n(x) \approx N_d(x) = n_0 e^{-ax}$

$\mathcal{E}(x) = \dfrac{kT}{q} a > 0 \quad \therefore \dfrac{d\varphi}{dx} < 0$



(a) B-doping



(b) P-doping

4.14

Use eq. (4-40)

$$J_p(x) = -qD_p\frac{dp}{dx} = -qD_p\frac{d\delta p}{dx} = q\frac{D_p}{L_p}\Delta p \cdot e^{-x/L_p}$$

At $x=0$. $$J_p = q\frac{D_p}{L_p}\Delta p$$

and $$\boxed{I_p(x=0) = qA\frac{D_p}{L_p}\Delta p}$$

Use integration

$$A\frac{q}{\tau_p}\int_0^\infty \delta p(x)\,dx = \frac{Aq}{\tau_p}\int_0^\infty \Delta p \cdot e^{-x/L_p}\,dx$$

$$= A\frac{\Delta p}{\tau_p} q L_p \cdot (e^0 - e^{-\infty})$$

$$= Aq\Delta p \cdot \frac{L_p}{\frac{L_p^2}{D_p}} = Aq\Delta p \cdot \frac{D_p}{L_p}$$