4.6

a.

(1)

$$J_n = \frac{eD_n n_{p0}}{L_n} = \frac{en_i^2}{N_A N_D} \cdot N_D \sqrt{D_n/\tau_{n0}} = 5.7 \times 10^{-11}\ A/cm^2$$

$$I_n = A \cdot J_n = 5.7 \times 10^{-15}\ A$$

$$J_p = \frac{eD_p p_{n0}}{L_p} = \frac{en_i^2}{N_A N_D} \cdot N_A \cdot \sqrt{D_p/\tau_{p0}} = 3.6 \times 10^{-10}\ A/cm^2$$

$$I_p = J_p \cdot A = 3.6 \times 10^{-14}\ A$$

(2)

$$p_{n0} = \frac{n_i^2}{N_D} = 2.25 \times 10^5\ cm^{-3}$$

$$p_n = p_{n0} \cdot \exp\left[\frac{eV_F}{k_B T}\right]$$

$$\because V_D = \frac{k_B T}{e} \ln\left(\frac{N_A N_D}{n_i^2}\right) = 0.617\ V$$

$$\therefore V_F = \frac{1}{2} V_D = 0.3085\ V$$

$$\therefore p_n = p_{n0} \cdot \exp\left[\frac{eV_F}{k_B T}\right] = 3.35 \times 10^{10}\ cm^{-3}$$

(3)

$$\Delta p_n(x) = p_n(x) - p_{n0} = p_{n0}\left[\exp\left(\frac{eV_F}{k_B T}\right) - 1\right] \exp\left(\frac{x_n - x}{L_p}\right)$$

$$\therefore J_p(x_n + \tfrac{1}{2}L_p) = eD_p \left.\frac{d(\Delta p_n(x))}{dx}\right|_{x = x_n + \frac{1}{2}L_p}$$

$$= eD_p \cdot p_{n0}\left[\exp\left(\frac{eV_F}{k_B T}\right) - 1\right] \cdot \frac{1}{L_p} \exp\left(\frac{-\frac{1}{2}L_p}{L_p}\right)$$

$$= \exp\left(-\frac{1}{2}\right) \cdot \frac{eD_p \cdot p_{n0}}{L_p}\left[\exp\left(\frac{eV_F}{k_B T}\right) - 1\right]$$

$$= \exp\left(-\frac{1}{2}\right) \cdot \frac{en_i^2}{N_A N_D} \cdot N_A \sqrt{D_p/\tau_{p0}} \cdot \left[\exp\left(\frac{eV_F}{k_B T}\right) - 1\right]$$

$$= 3.26 \times 10^{-5}\ A/cm^2$$

$$\therefore I_p = A \cdot J_p = 3.26 \times 10^{-9}\ A$$

b.

(1)

$$\Delta P_n(x) = P_{n0}\left[\exp\left(\frac{eV_F}{K_B T}\right)-1\right]\exp\left(\frac{x_n - x}{L_p}\right)$$

$$= \frac{n_i^2}{N_D}\left[\exp\left(\frac{eV_F}{K_B T}\right)-1\right]\exp\left(-\frac{x}{L_p}\right)$$

$$= 3.8\times10^{14}\exp(-3535x)$$

(2)

$$J_p = eD_p \left.\frac{d(\Delta P_n(x))}{dx}\right|_{x=3\times10^{-4}cm} = 0.596 \text{ A/cm}^2$$

$$J = J_p(x_n) + J_n(-x_p)$$

$$= \frac{en_i^2}{N_A N_D}\left(N_D\sqrt{D_n/\tau_{n0}} + N_A\sqrt{D_p/\tau_{p0}}\right)\cdot\left[\exp\left(\frac{eV_F}{K_B T}\right)-1\right]$$

$$= 1.98 \text{ A/cm}^2$$

$\therefore J_n = J - J_p = 1.390 \text{ A/cm}^2$

4.9

(1) $I_{PN} = I_S\left[\exp\left(\frac{eV_F}{K_B T}\right)-1\right] = A\cdot J_S\cdot\left[\exp\left(\frac{eV_F}{K_B T}\right)-1\right]$

$I_{ST} = A\cdot J_{ST}\cdot\left[\exp\left(\frac{eV_F}{K_B T}\right)-1\right]$

$\because I_{PN} = I_{ST}$

$\therefore A\cdot J_S\cdot\left[\exp\left(\frac{eV_{F1}}{K_B T}\right)-1\right] = A\cdot 5J_S\left[\exp\left(\frac{eV_{F2}}{K_B T}\right)-1\right] = 1\text{ mA}$

$\therefore V_{F1} = 0.705\text{V}, \quad V_{F2} = 0.467\text{V}$

(2) ① $I = I_{PN} + I_{ST} = (I_S + I_{ST})\left[\exp\left(\frac{eV_F}{K_B T}\right)-1\right]$

$\therefore V_F = 0.239\text{V}, \quad I_{PN} = 1.02\times10^{-8}\text{A}$

$I_T = 5.09\times10^{-4}\text{A}$

② $I_{PN} = I_T = 0.5\text{mA}$, $I_S\cdot\left[\exp\left(\frac{eV_F}{K_B T}\right)-1\right] = I_{ST}\cdot\left[\exp\left(\frac{eV_{F2}}{K_B T}\right)-1\right]$

$\therefore V_{F1} = 0.39\text{V}$ $V_{F2} = 0.156\text{V}$

补充题：

3.

(a) Ge是n型，GaAs是p型，形成异质结.

(b) $a_1 = 5.657$, $a_2 = 5.653$

$\frac{2|a_1 - a_2|}{a_1 + a_2} = 0.07\%$.

(c) $\Delta E_c = \chi_{Ge} - \chi_{GaAs} = 0.06\,eV$

(d) $\Delta E_g = 1.43 - 0.66 = 0.77\,eV$

$\Delta E_V = \Delta E_g - \Delta E_c = 0.71\,eV$

(e) $E_F - E_V = k_B T \ln\left(\frac{N_V}{N_A}\right) = 0.175\,eV$

(f) $E_c - E_f = k_B T \ln\left(\frac{N_C}{N_D}\right) = 0.201\,eV$

(g) $\varphi_{GaAs} \doteq \chi_1 + E_g - (E_f - E_V) = 5.33\,eV$

$\varphi_{Ge} \doteq \chi_2 + (E_c - E_f) = 4.33\,eV$

$\therefore eV_D = \varphi_{GaAs} - \varphi_{Ge} = 1eV$

(h) $x_n = \sqrt{\frac{2\varepsilon_n \varepsilon_p N_A N_D}{e N_D(\varepsilon_n N_D + \varepsilon_p N_A)}} = 4.91 \times 10^{-5}\,cm$

$x_p = \sqrt{\frac{2\varepsilon_n \varepsilon_p N_A N_D}{e N_A(\varepsilon_n N_D + \varepsilon_p N_A)}} = 2.76 \times 10^{-5}\,cm$

(i) $V_{PD} = \frac{eN_A x_p^2}{2\varepsilon_p} = 0.615\,eV$

$V_{DP} = \frac{eN_D x_n^2}{2\varepsilon_n} = 0.420\,eV$

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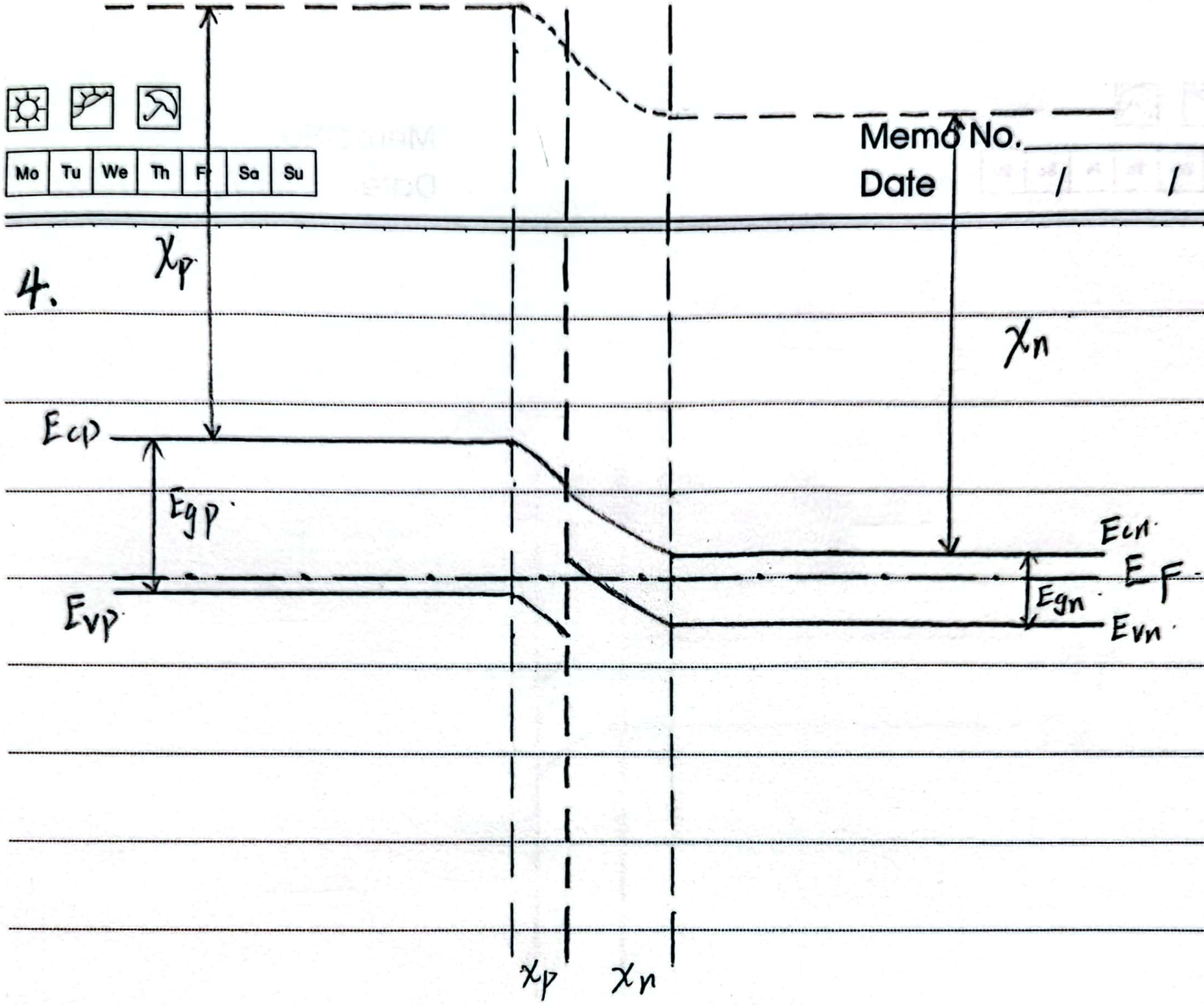
4.



5.