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ECE321
HW-5
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(2.11)

$N_D = 10^{18}\,cm^{-3}$
$N_A = 10^{16}\,cm^{-3}$
$T = 300\,K$

Minority carrier is holes, $(N_A > N_D)$

$$p_o = \frac{n_i^2}{N_D - N_A} = \frac{\left(1.062\times10^{10}\,\frac{\text{carriers}}{cm^3}\right)^2}{10^{18}\,cm^{-3} - 10^{16}\,cm^{-3}} = \boxed{113.9\ \frac{\text{holes}}{cm^3}}$$

(2-15)

$p_o = N_A = 10^{18}\,cm^3$ at $T = 280\,K$ (p-sub)

$\mu_n = 1500\ cm^2/V\cdot s$, $\mu_p = 500\ cm^2/V\cdot s$

a) $$E = \frac{1V}{20\mu m} = \frac{5\,000\,V}{m} = \boxed{\frac{500\,V}{cm}}$$

b) $$n_i = (5.23\times10^{15})(280)^{3/2} e^{\frac{-1.12}{2kT/q}} = 2.04\times10^{9}\,\frac{\text{carriers}}{cm^3}$$

$$n_o = \frac{n_i^2}{N_A} = 4.16\ \frac{\text{electrons}}{cm^3}$$

c) $$J = \mu_p q E p_o = (500\,cm^2/V\text{-}s)(1.602\times10^{-19}C)(500\,V/cm)(10^{18}\,cm^{3})$$
$$= \boxed{40.05\ kA/cm^2}$$

d) $$1\,\mu m^2 = (1.00\times10^{-6})^2\,cm^2$$

$$J = \frac{40.05\,kA/cm^2}{(10{,}000)^2} = \boxed{400.5\,\mu A/\mu m^2}$$

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(2-16)

a) n-doped, $\mu_n = 1200\,cm^2/V\text{-}s$
$T = 325\,K$
$N_D = 10^{18}$
$J_n = 10\,kA/cm^2$

$$E = \frac{J_{dn}}{\mu_n q\, n_o} = \frac{10\,kA/cm^2}{(1200\,cm^2/V\text{-}s)(1.602\times10^{-19})(10^{18})}$$

$$= \boxed{52.02\ V/cm}$$

b) $$d = \frac{2V}{52.02\ V/cm} = 38.44\,m\,cm = \boxed{384.48\,\mu m}$$

(2-17) $$J = \frac{E}{\rho} \Rightarrow \rho = \frac{E}{J} = \frac{52.02\ V/cm}{10\,kA/cm^2} = \boxed{5.2\,m\Omega\text{-}cm}$$

$$J = \sigma E \Rightarrow \sigma = \frac{J}{E} = \boxed{192.24\ S/cm}$$

(2-22)

$\mu_n = 1300\,cm^2/V\text{-}s$
$\mu_p = 400\,cm^2/V\text{-}s$
$dn_o/dx = 10^{20}\,cm^{-1}$
$dp_o/dx = 10^{17}\,cm^{-1}$

$$D_p = \frac{kT}{q}\mu_p = (26\,mV)(400\,cm^2/V\text{-}s) = 10.4\ cm^2/s$$

$$D_n = \frac{kT}{q}\mu_n = (26\,mV)(1300\,cm^2/V\text{-}s) = 33.8\ cm^2/s$$

$$J_{ndiff} = q D_n\, dn_o/dx = (1.602\times10^{-19}\,C)(33.8\,cm^2/s)(10^{20}\,cm^{-1})$$

$$= \boxed{541.48\ A/cm^2}$$

(2-25) $T = 345\,K$
$N_A = 10^{18}\,cm^{-3}$
$N_D = 10^{15}\,cm^{-3}$

$$n_i = BT^{3/2} e^{\frac{-E_g}{2kT/q}} = 219.7\times10\ \frac{carriers}{cm^3}$$

$$V_{bi} = \frac{kT}{q}\ln\left(\frac{N_A N_D}{n_i^2}\right) = \frac{(1.38\times10^{-23}\,J/K)(345\,K)}{1.602\times10^{-19}\,C}\ln\left[\frac{(10^{18}\,cm^{-3})(10^{15}\,cm^{-3})}{219.7\times10^{9}}\right]$$

$$= \boxed{0.706\ V}$$

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(2-30) pn junction, forward biased

Room temperature $\Rightarrow V_{TH} = 26mV$

Let $I_D = 1mA = I_S$

$$100 I_D = I_S\left(e^{V_D x / V_{TH}} - 1\right)$$

$$100mA = 1mA\left(e^{x/.026} - 1\right)$$

$$x = (.026)\ln(100) = \boxed{119.7}$$

(2-31) $C_{jo} = 2pF$
$V_{bi} = 0.65V$

$V_R = 1V$: $C_j = \dfrac{C_{jo}}{\left(1 + \frac{V_R}{V_{bi}}\right)^{1/2}} = \dfrac{2pF}{\left(1 + \frac{1}{0.65}\right)^{1/2}} = \boxed{1.26pF}$

$V_R = 2V$: $C_j = \dfrac{2pF}{\left(1 + \frac{2}{0.65}\right)^{1/2}} = \boxed{990.3fF}$

$V_R = 3V$: $C_j = \dfrac{2pF}{\left(1 + \frac{3}{0.65}\right)^{1/2}} = \boxed{844fF}$