VE320 HW9 周雅凯 5180219011039

1.(a). When $V_{GS}=0.5V$

$$I_D=10^{-15}\exp\left(\frac{0.5}{2.1\times0.0\times59}\right)=9.83\times10^{-12}A. \Rightarrow I_t=10^6 I_D=9.83\times10^{-6}A.$$

When $V_{GS}=0.7V$

$$I_D=10^{-15}\exp\left(\frac{0.7}{2.1\times0.0\times59}\right)=3.88\times10^{-10}A. \Rightarrow I_t=10^6 I_D=3.88\times10^{-4}A.$$

When $V_{GS}=0.9V$

$$I_D=10^{-15}\exp\left(\frac{0.9}{2.1\times0.0\times59}\right)=1.54\times10^{-8}A. \Rightarrow I_t=10^6 I_D=1.54\times10^{-2}A.$$

(b). When $V_{GS}=0.5V$

$$P=I_t\cdot V_{DD}=4.92\times10^{-5}\ W$$

When $V_{GS}=0.7V$

$$P=I_t\cdot V_{DD}=1.94\times10^{-3}\ W$$

When $V_{GS}=0.9V$

$$P=I_t\cdot V_{DD}=0.077\ W$$

2.(a).(i). $V_{DS}>V_{GS}-V_T$

$$I_D=\frac{k_n'}{2}\cdot\frac{W}{L}(V_{GS}-V_T)^2=75.94\ \mu A$$

(ii). $I_D'=I_D(1+\lambda V_{DS})=78.22\ \mu A$

(iii). $r_o=\frac{1}{\lambda I_D}=6.58\times10^5\ \Omega$

(b).(i). $V_{DS}>V_{GS}-V_T$

$$I_D=\frac{k_n'}{2}\cdot\frac{W}{L}(V_{GS}-V_T)^2=303.75\ \mu A$$

(ii). $I_D'=I_D(1+\lambda V_{DS})=312.86\ \mu A$

(iii). $r_o=\frac{1}{\lambda I_D}=1.65\times10^5\ \Omega$

3.(a).(i). $V_{DS}<V_{GS}-V_T$

$$C_{ox}=\frac{\varepsilon_{ox}}{t_{ox}}=\frac{3.9\times8.85\times10^{-14}}{200\times10^{-8}}=1.726\times10^{-7}\ F/cm^2$$

$$I_D=\mu_n C_{ox}\frac{W}{L}\left(V_{GS}-V_T-\frac{V_{DS}}{2}\right)V_{DS}=7.17\times10^{-4}A$$

(ii). $V_{DS}<V_{GS}-V_T$

$$I_D=1.23\times10^{-3}A$$

(iii). $V_{DS} < V_{GS} - V_T$

$I_D = 1.41 \times 10^{-3} A$

(iv). $V_{DS} = V_{GS} - V_T$

$I_D = \mu_n C_{ox} \frac{W}{2L} (V_{GS} - V_T)^2 = 1.64 \times 10^{-3} A.$

(b).(i). When $V_{DS} = 0.5\,V$, $v_{ds} = \frac{0.5}{1.25} \times 4 \times 10^6 = 1.6 \times 10^6$ cm/s

$I_D = W C_{ox} (V_{GS} - V_T) v_{ds} = (10 \times 10^{-4}) \times 1.736 \times 10^{-7} \times 2 \times 1.6 \times 10^6 = 5.52 \times 10^{-4} A.$

(ii). When $V_{DS} = 1.0\,V$, $v_{ds} = \frac{1}{1.25} \times 4 \times 10^6 = 3.2 \times 10^6$ cm/s

$I_D = W C_{ox} (V_{GS} - V_T) v_{ds} = 1.10 \times 10^{-3} A$

(iii). When $V_{DS} = 1.25\,V$, $v_{ds} = 4 \times 10^6$ cm/s

$I_D = 1.38 \times 10^{-3} A$

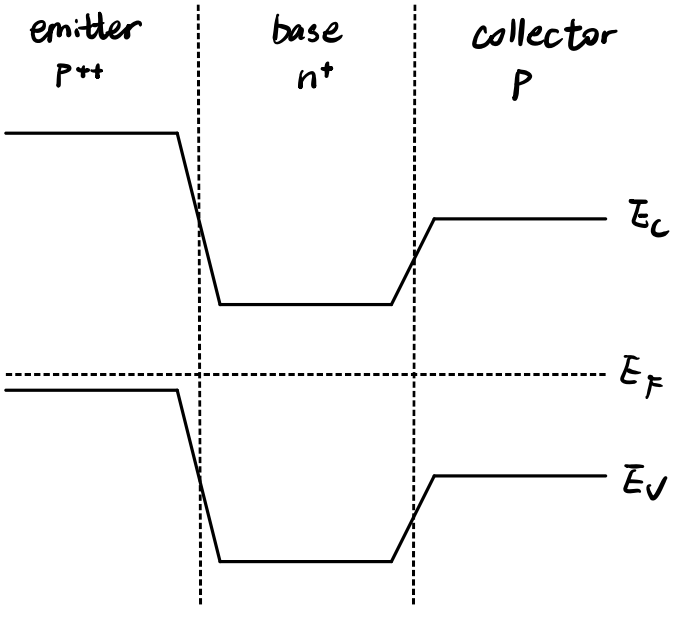
(iv). When $V_{DS} = 2\,V$, $v_{ds} = 4 \times 10^6$ cm/s

$I_D = 1.38 \times 10^{-3} A$

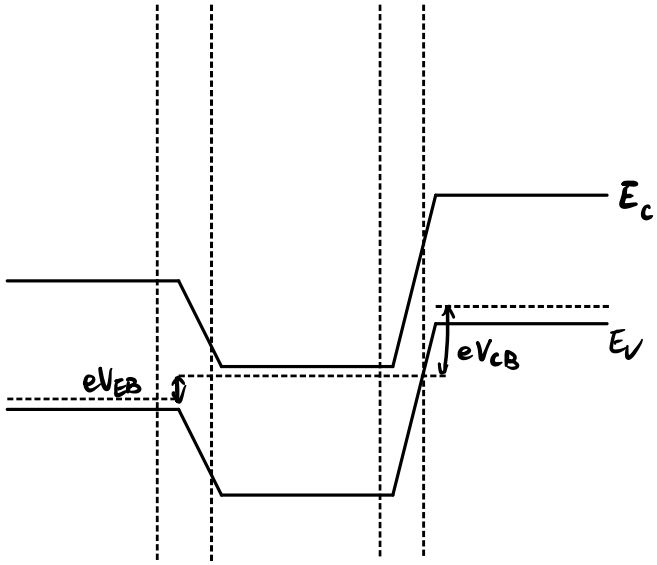
(c). For (a). $V_{DS}(sat) = 2\,V$

For (b). $V_{DS}(sat) = 1.25\,V$

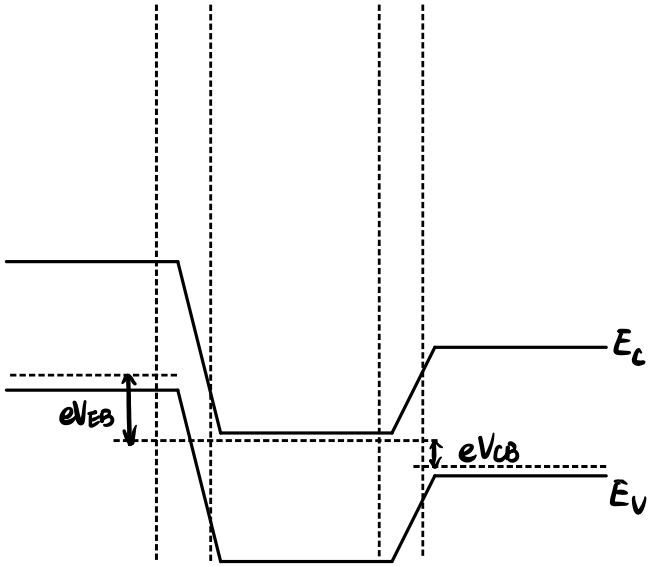
4. (a).



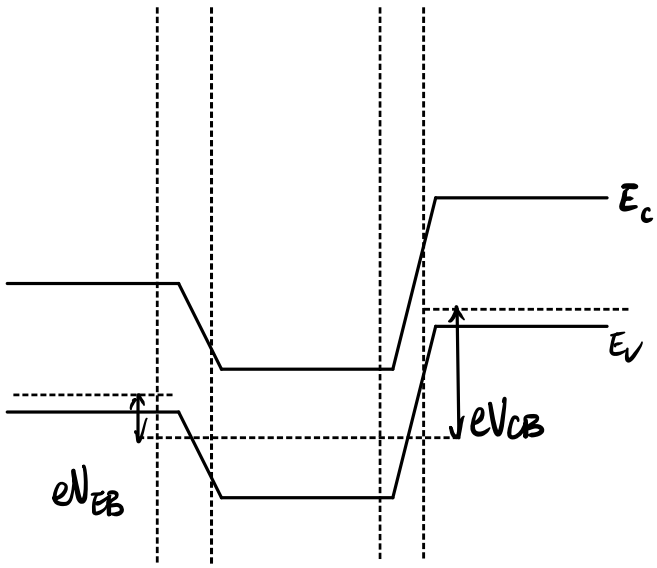
(b).



(c).



(d).



5.(a). $P_{E0} = \frac{n_i^2}{N_E} = 281.25 \ cm^{-3}$

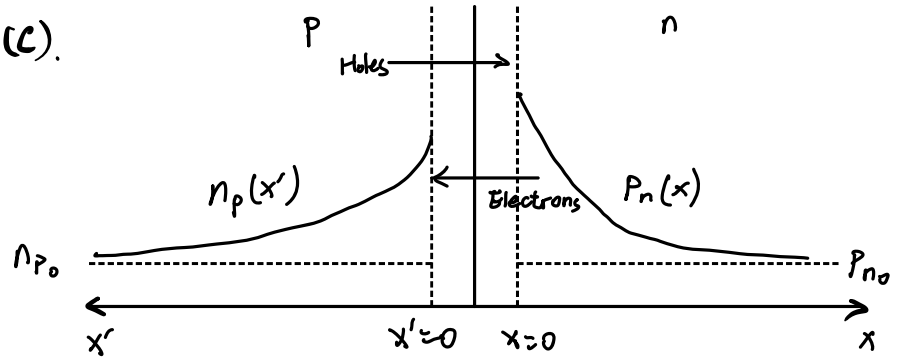
$n_{B0} = \frac{n_i^2}{N_B} = 1.125 \times 10^4 \ cm^{-3}$

$P_{C0} = \frac{n_i^2}{N_C} = 2.25 \times 10^5 \ cm^{-3}$

(b). $n_B(0) = n_{B0} \exp\left(\frac{V_{BE}}{V_t}\right) = 6.06 \times 10^{14} \ cm^{-3}$

$P_E(0) = P_{E0} \exp\left(\frac{V_{BE}}{V_t}\right) = 1.52 \times 10^{13} \ cm^{-3}$

(c).



b.(a). $x_{dB} = \sqrt{\frac{2\varepsilon_s(V_{bi} + V_{BC})}{e} \frac{N_C}{N_B} \frac{1}{N_C + N_B}}$

$V_{bi} = V_t \ln\left(\frac{N_C N_B}{n_i^2}\right) = 0.635 \ V$

For $V_{BC} = 1V$, $x_{dB} = 1.387 \times 10^{-5} \ cm$

For $V_{BC} = 5V$, $x_{dB} = 2.575 \times 10^{-5} \ cm$

$\Delta x_{dB} = 1.188 \times 10^{-5} \ cm$

(b). $I_C = \frac{e D_B P_{B0} A_{BE}}{x_B} \exp\left(\frac{V_{EB}}{V_t}\right)$

$P_{B0} = \frac{n_i^2}{N_B} = 2250 \ cm^{-3}$

For $V_{BC} = 1V$, $x_B = 0.7 \times 10^{-4} - 1.387 \times 10^{-5} = 5.613 \times 10^{-5} \ cm$

$I_C = 1.94 \times 10^{-3} \ A$

For $V_{BC} = 5V$, $x_B = 0.7 \times 10^{-4} - 2.575 \times 10^{-5} = 4.425 \times 10^{-5}$ cm

$$I_C = 2.46 \times 10^{-3} A$$

$$\Delta I_C = 5.17 \times 10^{-4} A$$

(c). $$\frac{\Delta I_C}{\Delta V_{BC}} = \frac{I_C}{V_{EC} + V_A}$$

$$\frac{5.17 \times 10^{-4}}{5-1} = \frac{1.94 \times 10^{-3}}{1 + 0.625 + V_A} \Rightarrow V_A = 13.38\ V$$

(d). $$r_o = \frac{V_{EC} + V_A}{I_C} = \frac{1.625 + 13.38}{1.94 \times 10^{-3}} = 7.73 \times 10^3\ \Omega$$