EE 207 (MBP): Question Set 2

1. For an abrupt silicon pn junction at 300 K with $N_a = 5 \times 10^{17}\,\text{cm}^{-3}$ and $N_d = 8 \times 10^{16}\,\text{cm}^{-3}$, what is the built-in voltage V_{bi}?
   ($n_i = 1.5 \times 10^{10}\,\text{cm}^{-3}$ at 300 K.)

   (A) 0.59 V (B) 0.67 V (C) 0.73 V (D) 0.85 V

2. For the conditions given in Q-1, what is the total depletion width W?

   (A) 0.530 μm (B) 0.284 μm (C) 0.126 μm (D) 0.098 μm

3. For the conditions given in Q-1, what is W_n (depletion width on the n-side)?

   (A) 0.109 μm (B) 0.084 μm (C) 0.145 μm (D) 0.056 μm

4. For the conditions given in Q-1, what is W_p (depletion width on the p-side)?

   (A) 0.102 μm (B) 0.074 μm (C) 0.122 μm (D) 0.017 μm

5. For the conditions given in Q-1, what is $\mathcal{E}_m$, the maximum electric field (magnitude) in equilibrium?

   (A) 85 kV/cm (B) 134 kV/cm (C) 215 kV/cm (D) 178 kV/cm

6. For the conditions given in Q-1, what is the slope of the electric field $d\mathcal{E}/dx$ (magnitude) in the depletion region on the n side?

   (A) 1.24×10^{10} V/cm^2
   (B) 6.56×10^{10} V/cm^2
   (C) 3.85×10^{9} V/cm^2
   (D) 7.90×10^{9} V/cm^2

7. For the conditions given in Q-1, what is the slope of the electric field $d\mathcal{E}/dx$ (magnitude) in the depletion region on the p side?

   (A) 3.42×10^{11} V/cm^2
   (B) 6.82×10^{11} V/cm^2
   (C) 7.74×10^{10} V/cm^2
   (D) 1.25×10^{10} V/cm^2

8. Consider an abrupt silicon pn junction at $T = 300$ K with $N_d = 10^{17}\,\text{cm}^{-3}$. If $W_p/W_n = 3$ in equilibrium, what is N_a?

   (A) 1.11×10^{16} cm^{-3}
   (B) 3.33×10^{16} cm^{-3}
   (C) 2.5×10^{16} cm^{-3}
   (D) 3×10^{17} cm^{-3}

9. Consider an abrupt silicon n^+p junction at 300 K with $N_d = 10^{18}\,\text{cm}^{-3}$ and $N_a = 10^{16}\,\text{cm}^{-3}$. If the critical field for breakdown $\mathcal{E}_c$ for silicon is 300 kV/cm, what is the reverse breakdown voltage for this junction?

($n_i = 1.5 \times 10^{10}\,\mathrm{cm}^{-3}$ at 300 K.)

(A) 35 V (B) 19 V (C) 43 V (D) 28 V

10. For the n^+p junction described in Q-9, what is the reverse breakdown voltage for this junction if $N_a = 5 \times 10^{16}\,\mathrm{cm}^{-3}$?

    (A) 6.8 V (B) 9.2 V (C) 5 V (D) 3.5 V

11. For an abrupt silicon pn junction with $N_a = 10^{18}\,\mathrm{cm}^{-3}$, $N_d = 10^{16}\,\mathrm{cm}^{-3}$, what is dV_{bi}/dT (in mV/°C) at $T = 300\,\mathrm{K}$? (Take into account the temperature dependence of V_T as well as n_i^2. Assume that N_c, N_v, E_g vary slowly with temperature, i.e., they can be treated as constants. At 300 K, $n_i = 1.5 \times 10^{10}\,\mathrm{cm}^{-3}$, $E_g = 1.1\,\mathrm{eV}$.)

    (A) -0.97 mV/K (B) -1.50 mV/K (C) -0.54 mV/K (D) -2.18 mV/K

12. Consider a reverse-biased p^+n silicon junction at 300 K. We want to design the junction for a breakdown voltage of $V_{\mathrm{BR}} = 10\,\mathrm{V}$. What is the maximum value of N_d we can use? (Assume the critical field $\mathcal{E}_c$ for silicon to be 300 kV/cm and $V_{\mathrm{bi}} \approx 0.8\,\mathrm{V}$.)

    (A) $1.8 \times 10^{17}\,\mathrm{cm}^{-3}$
    (B) $2.7 \times 10^{16}\,\mathrm{cm}^{-3}$
    (C) $9.6 \times 10^{15}\,\mathrm{cm}^{-3}$
    (D) $2.2 \times 10^{15}\,\mathrm{cm}^{-3}$

13. With a forward bias of 0.62 V, a silicon pn diode conducts a current of 0.5 mA. Assume the ideality factor η to be 1 and $T = 300\,\mathrm{K}$. What is I_s (the reverse saturation current)?

    (A) $3.9 \times 10^{-13}\,\mathrm{A}$
    (B) $8.1 \times 10^{-14}\,\mathrm{A}$
    (C) $7.6 \times 10^{-13}\,\mathrm{A}$
    (D) $2.0 \times 10^{-14}\,\mathrm{A}$

14. For the diode described in Q-13, what forward voltage should be applied to obtain a current of 2.5 mA?

    (A) 0.72 V (B) 0.76 V (C) 0.66 V (D) 0.61 V

15. The fact that n_i nearly doubles with every 10 °C rise in temperature can be represented by the equation, $n_i = Ke^{\alpha T}$, where T is in Kelvin. What is α?

    (A) 0.0693 (B) 0.693 (C) 0.139 (D) 0.0347

16. For the diode described in Q-13, the applied voltage is $V = 0.62\,\mathrm{V}$. What is the diode current if the temperature increases by 5 °C? (Assume that n_i doubles every 10 °C for silicon. Ignore the other temperature dependencies in I_s, and assume E_g to be constant and equal to 1.1 eV.)

    (A) 2 mA (B) 1 mA (C) 1.53 mA (D) 0.67 mA

17. Consider an abrupt silicon pn junction under moderate forward bias, with $N_a = 10^{17}\,\text{cm}^{-3}$, $\tau_p = 10\,\text{ns}$, $\tau_n = 20\,\text{ns}$, $\mu_n = 1000\,\text{cm}^2/\text{V-s}$, $\mu_p = 400\,\text{cm}^2/\text{V-s}$, $T = 300\,\text{K}$. The hole current $I_p(x_n)$ is twice as large as the electron current $I_n(x_p)$. What is N_d?

(A) $4.5 \times 10^{16}\,\text{cm}^{-3}$
(B) $1.8 \times 10^{17}\,\text{cm}^{-3}$
(C) $7.8 \times 10^{17}\,\text{cm}^{-3}$
(D) $9.6 \times 10^{16}\,\text{cm}^{-3}$

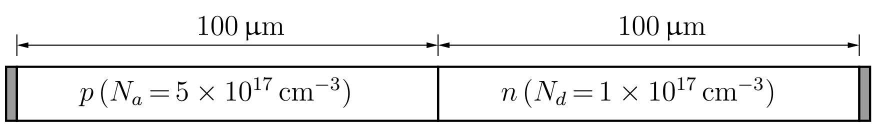
18. Consider a p^+n silicon diode with $\mu_p = 500\,\text{cm}^2/\text{V-s}$, $N_d = 5 \times 10^{16}\,\text{cm}^{-3}$, $\tau_p = 50\,\text{ns}$, an area of $10^4\,\mu\text{m}^2$, operating at $T = 300\,\text{K}$. What is I_s? ($n_i = 1.5 \times 10^{10}\,\text{cm}^{-3}$)

(A) $2.08 \times 10^{-14}\,\text{A}$
(B) $1.15 \times 10^{-15}\,\text{A}$
(C) $9.80 \times 10^{-15}\,\text{A}$
(D) $7.66 \times 10^{-14}\,\text{A}$

19. For the diode described in Q-18, the applied forward voltage is $V = 0.68\,\text{V}$. What is the diode current?

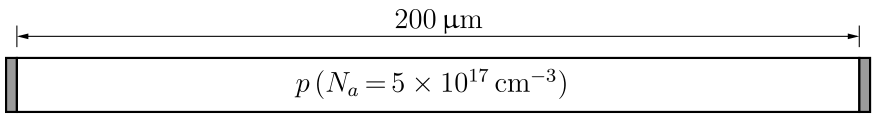
(A) 0.30 mA (B) 2.08 mA (C) 7.51 mA (D) 0.66 mA

20. For the silicon pn diode shown in the figure, $N_a = 5 \times 10^{17}\,\text{cm}^{-3}$, $N_d = 10^{17}\,\text{cm}^{-3}$, $\tau_p = \tau_n = 0.1\,\mu\text{s}$, $\mu_n = 1200\,\text{cm}^2/\text{V-s}$, $\mu_p = 400\,\text{cm}^2/\text{V-s}$, the cross-sectional area is $10^{-4}\,\text{cm}^2$, and $T = 300\,\text{K}$. For a forward bias of 0.7 V, what is the diode current?
($n_i = 1.5 \times 10^{10}\,\text{cm}^{-3}$ at 300 K.)



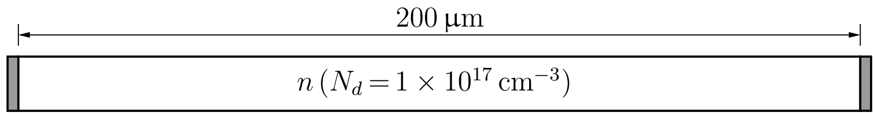
(A) 0.42 mA (B) 1.60 mA (C) 0.28 mA (D) 3.73 mA

21. The figure shows a structure with a constant doping density. It has the same dimensions as the pn junction structure of Q-20. What voltage should be applied to get the same current as that for the pn junction of Q-20 with a forward bias of 0.7 V?



(A) 5.9 mV (B) 1.8 mV (C) 25 mV (D) 40 mV

22. The figure shows a structure with a constant doping density. It has the same dimensions as the pn junction structure of Q-20. What voltage should be applied to get the same current as that for the pn junction of Q-20 with a forward bias of 0.7 V?



(A) 15.8 mV (B) 1.56 mV (C) 25.3 mV (D) 2.95 mV