Homework #5

pn Junction Operation and Small Signal Model – *100 points*
DUE @ Beginning of Class: Thursday, October 12

****Make sure to use the "Note" on page 251.**

1) E-Book, problem 8.3 (12 points)

2) E-Book, problem 8.8, you can use the ideal diode equation (10 points)

3) E-Book, problem 8.10, you can approximate the current as $I = I_s e^{\frac{V_a}{V_t}}$ (16 points)

4) E-Book, problem 8.15, you can use the ideal diode equation (20 points)

5) E-Book, problem 8.28 (12 points)

6) E-Book, problem 8.37 (8 points)

7) E-Book, problem 8.42, (16 points)

8) E-Book, problem 1.38 (pg. 443) (6 points)

1) E-Book, problem 8.3 (12 points)

8.3 The doping concentrations in a GaAs pn junction are $N_d = 10^{16}\ \text{cm}^{-3}$ and $N_a = 4 \times 10^{16}\ \text{cm}^{-3}$. Find the minority carrier concentrations at the edges of the space charge region for (*a*) $V_a = 0.90$ V, (*b*) $V_a = 1.10$ V, and (*c*) $V_a = -0.95$ V.

2) E-Book, problem 8.8, you can use the ideal diode equation (10 points)

8.8 A one-sided p^+n silicon diode has doping concentrations of $N_a = 5 \times 10^{17}$ cm^{-3} and $N_d = 8 \times 10^{15}$ cm^{-3}. The minority carrier lifetimes are $\tau_{n0} = 10^{-7}$ s and $\tau_{p0} = 8 \times 10^{-8}$ s. The cross-sectional area is $A = 2 \times 10^{-4}$ cm^2. Calculate the (*a*) reverse-biased saturation current, and (*b*) the forward-bias current at (*i*) $V_a = 0.45$ V, (*ii*) $V_a = 0.55$ V, and (*iii*) $V_a = 0.65$ V.

3) E-Book, problem 8.10, you can approximate the current as $I = I_s e^{\frac{V_a}{V_t}}$ (16 points)

8.10 Fill in the missing data in the following table.

Case	V_a (V)	I (mA)	I_s (mA)	J_s (mA/cm^2)	A (cm^2)
1	0.65	0.50			2×10^{-4}
2	0.70		2×10^{-12}		1×10^{-3}
3		0.80		1×10^{-7}	1×10^{-4}
4	0.72	1.20		2×10^{-8}	

4) E-Book, problem 8.15, you can use the ideal diode equation (20 points)

8.15 A silicon pn junction with a cross-sectional area of 10^{-4} cm^2 has the following properties at $T = 300$ K:

n region	p region
$N_d = 10^{17}$ cm^{-3}	$N_a = 5 \times 10^{15}$ cm^{-3}
$\tau_{p0} = 10^{-7}$ s	$\tau_{n0} = 10^{-6}$ s
$\mu_n = 850$ cm^2/V-s	$\mu_n = 1250$ cm^2/V-s
$\mu_p = 320$ cm^2/V-s	$\mu_p = 420$ cm^2/V-s

(a) Sketch the thermal equilibrium energy-band diagram of the pn junction, including the values of the Fermi level with respect to the intrinsic level on each side of the junction. (b) Calculate the reverse-saturation current I_s and determine the forward-bias current I at a forward-bias voltage of 0.5 V. (c) Determine the ratio of hole current to total current at the space charge edge x_n.

5) E-Book, problem 8.28 (12 points)

8.28 Consider a silicon pn junction diode with an applied reverse-biased voltage of $V_R = 5$V. The doping concentrations are $N_a = N_d = 4 \times 10^{16}$ cm^{-3} and the cross-sectional area is $A = 10^{-4}$ cm^2. Assume minority carrier lifetimes of $\tau_0 = \tau_{n0} = \tau_{p0} = 10^{-7}$ s. Calculate the (*a*) ideal reverse-saturation current, (*b*) reverse-biased generation current, and (*c*) the ratio of the generation current to ideal saturation current.

6) E-Book, problem 8.37 (8 points)

8.37 (*a*) Calculate the small-signal diffusion capacitance and diffusion resistance of a silicon pn junction diode biased at $I_{DQ} = 1.2$ mA. Assume the minority carrier lifetimes are 0.5 μs in both the n and p regions. (*b*) Repeat part (*a*) for the case when the diode is biased at $I_{DQ} = 0.12$ mA.

7) E-Book, problem 8.42, (16 points)

8.42 A one-sided p^+n silicon diode has doping concentrations of $N_a = 4 \times 10^{17}$ cm^{-3} and $N_d = 8 \times 10^{15}$ cm^{-3}. The diode cross-sectional area is $A = 5 \times 10^{-4}$ cm^2. (*a*) The maximum diffusion capacitance is to be limited to 1 nF. Determine (*i*) the maximum current through the diode, (*ii*) the maximum forward-bias voltage, and (*iii*) the diffusion resistance. (*b*) Repeat part (*a*) if the maximum diffusion capacitance is limited to 0.25 nF.

8) E-Book, problem 1.38 (pg. 443) (6 points)

1.38 A pn junction diode is in series with a 1 MΩ resistor and a 2.8 V power supply. The reverse-saturation current of the diode is $I_S = 5 \times 10^{-11}$ A.
(a) Determine the diode current and voltage if the diode is forward biased.
(b) Repeat part (a) if the diode is reverse biased.