Compensation Doping

2-11. If $N_D = 10^{18}\text{cm}^{-3}$ and $N_A = 10^{16}\text{ cm}^3$, calculate the minority carrier dopant concentration at $T = 300$ K.

2-12. Repeat Problem 2.11 if the temperature is elevated 50°C.

2-13. In a compensated semiconductor, $p_o = 4 \times 10^6\text{ cm}^{-3}$ and $N_D - N_A = 4.99 \times 10^{18}\text{ cm}^{-3}$. What is the temperature for this condition?

2-14. If $T = 390$ K, $N_D = 5 \times 10^{18}$, and minority carrier concentration is $1.1 \times 10^6\text{ cm}^{-3}$, what is the minority carrier doping concentration in a compensated semiconductor?

Carrier Transport—Drift Current

2-15. A p-silicon material has $p_o = N_A = 10^{18}$ cm^3 at 280 K. $\mu_n = 1500$ (cm^2/V · s), and $\mu_p = 500$ (cm^2/V · s). The semiconductor has 1 V across a 20 μm dimension.
(a) What is the electric field in V/cm?
(b) What is the electron carrier density n_o?
(c) What is the current density J (A/cm^2)?
(d) What is the current density J (A/μm^2)?

2-16. **(a)** Neglect minority carrier current density in an n-doped semiconductor. If $\mu_n = 1200$ cm^2/V·s at $T = 325$ K, $N_D = 10^{18}$ and current density is $J_n = 10$ kA/cm^2, what is the electric field?
(b) If 2 V causes this E-field across the material, what is the material dimension in microns?

2-17. What are the conductivity and resistivity in Problem 2.16?

2-18. The current density is $J = 300$ A/cm^2, conductivity $\sigma = 0.5$ A/V · cm, and $\mu_n = 1350$ cm^2/V · s. What is the donor doping concentration?

Carrier Transpor—Diffusion Current

2-19. If an electron concentration gradient is 4×10^{18} electrons/cm^3 and $D_n = 25$ cm^2/s, what is the diffusion current?

2-20. $D_n = 35$ cm^2/s, $D_p = 12$ cm^2/s, $J = 15$ mA/cm^2, the free electron concentration gradient is three times that of the free hole concentration. What are the free carrier concentration gradients?

2-21. At room temperature, $D_n = 35$ cm^2/s and $D_p = 10$ cm^2/s. What are μ_n and μ_p?

2-22. At room temperature $\mu_n = 1300$ (cm^2/V · s) and $\mu_p = 400$ (cm^2/V · s). If electron and hole concentration gradients are 10^{20} cm^{-1} and 10^{17} cm^{-1}, what is total current density?

pn Junction Diodes

2-23. A pn junction has $N_A = 10^{15}\text{cm}^{-3}$, $N_D = 10^{16}\text{cm}^{-3}$, and $T = 300$ K. Calculate V_{bi}.

2-24. A pn junction has $N_D = 10^{18}\text{ cm}^{-3}$ and $N_A = 10^{16}\text{ cm}^{-3}$.
(a) Calculate V_{bi} at $T = 300$ K.
(b) Calculate V_{bi} at $T = 400$ K.

2-25. Calculate the built-in potential of a pn junction if $T = 345$ K, acceptor doping is 10^{18} cm^{-3}, and donor doping is 10^{15} cm^{-3}.

2-26. If $N_D = 10^{17}$, $T = 300$ K, and $V_{bi} = 0.725$ V, what must N_A be set at?

2-27. If $N_D = 10^{17}$, $T = 420$ K, and $V_{bi} = 0.725$ V, what must N_A be set at?

2-28. A diode has $I_s = 10$ pA, $T = 300$ K, and $V_D = 0.625$ V. What is the diode current I_D?

2-29. The diode equation is $I_D = I_S\left(e^{V_D/V_T} - 1\right)$. The -1 term becomes negligible with respect to the exponential in most forward bias situations and can be neglected. At what value of V_D does the exponential become ten times greater than the one term? Assume room temperature.

2-30. A silicon pn junction is operating in the forward bias region. Determine the increase in forward bias voltage that will cause a factor of 100 increase in the diode current. Assume room temperature.

pn Junction Capacitance

2-31. A pn junction diode has $C_{j0} = 2$ pF and $V_{bi} = 0.65$ V. Calculate the reverse bias depletion capacitance for reverse bias voltages of 1 V, 2 V, and 3 V.

2-32. Given a *pn* junction diode with a reverse bias of 4 V. $C_{j0} = 50$ fF, $T = 350$ K, $N_A = 10^{15}$ cm^{-3}, and $N_D = 10^{16}$ cm^{-3}. Calculate C_j.

2-33. A *pn* junction diode has a reverse bias capacitance $C_j = 80$ fF, $C_{jo} = 150$ fF, and a reverse bias voltage of 2 V. What is V_{bi}?

2-34. A diode has $N_A = 10^{15}$ cm^{-3}, $N_D = 10^{18}$ cm^{-3}, $T = 390$ K, $C_{j0} = 100$ pF, and $V_R = 2$ V. Calculate C_j the depletion capacitance.

2-35. Calculate the junction capacitance of a reverse biased *pn* junction when given $T = 400$ K, $C_{j0} = 50$ fF, $N_A = 10^{14}$ cm^{-3}, $N_D = 10^{18}$ cm^{-3}, and reverse bias voltage is $V_R = 2$ V.