Excercise 1: Semiconductors / pn-junctions

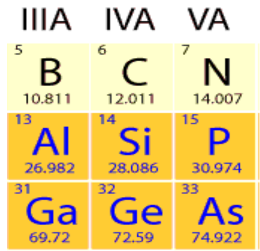
Carrier concentrations

1. Consider undoped GaAs (N_c=4.7x10^{17} cm^{-3}, N_v=7.0x10^{18} cm^{-3}, E_g=1.424 eV) and Si (N_c=2.8x10^{19} cm^{-3}, N_v=1.04x10^{19}, cm^{-3}, E_g=1.12 eV). At what temperature is the intrinsic carrier density of GaAs equal to that of Si at 200K?

Transport

2. Find the resistivity at 300 K for a Si sample doped with

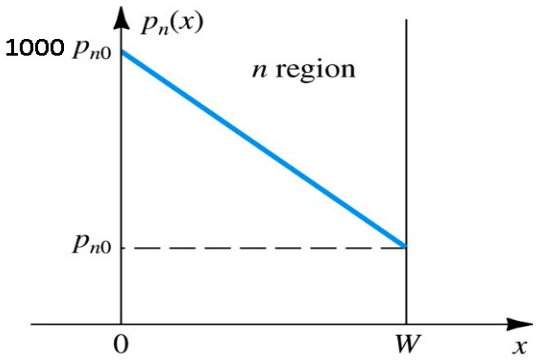
Phosphorus (P): 1.0x10^{14} cm^{-3}
Arsenic (As): 8.5x10^{12} cm^{-3}
Boron (B): 1.2x10^{13} cm^{-3}



The electron mobility of Si is μ_n=1500 cm^2/Vs and the hole mobility μ_p=500 cm^2/Vs. Hint: the dopants can be either acceptors or donors depending on the group in the periodic table of elements.

3. Calculate the electron and hole drift velocities through a 10-µm thick layer of intrinsic silicon across which a voltage of 1V is applied. Let μ_n = 1350 cm^2/Vs and μ_p = 480 cm^2/Vs.

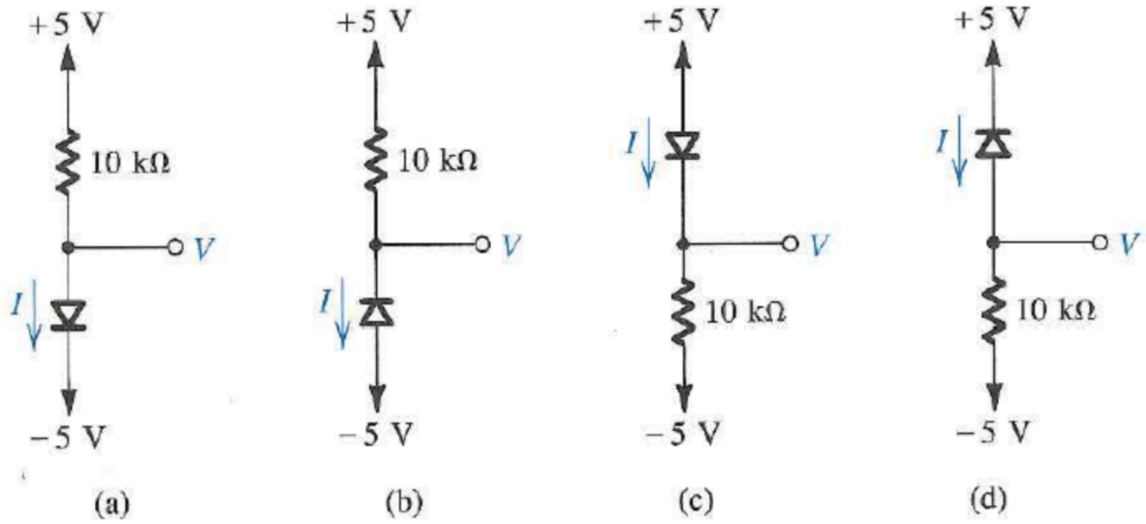
4. Holes (minority carriers) are steadily injected into a piece of n-doped Si (N_D=10^{16} cm^{-3}) at x=0 and extracted at x=W resulting in the hole concentration shown in the image below, where p_{n0} is the hole carrier concentration at equilibrium (no injection i.e. no bias). Use an intrinsic carrier concentration of n_i=1.5*10^{10} cm^{-3} and W=5 µm. The hole mobility is μ_p = 480 cm^2/Vs. Calculate the current density that flows in the x-direction.



pn-junctions / diodes

5. (1.84 in Sedra/Smith 7e) Calculate the built-in voltage of a junction in which the p and n regions are doped equally with 5e16 cm^{-3}. Assume n_i=1.5e10 cm^{-3} (Si at room temp). With the terminals left open (no bias applied), what is the width of the depletion region, and how far does it extend into the p and n regions? If the cross sectional area of the junction is 20 μm^{-2}, find the magnitude of the charge stored on either side of the junction.

6. For the circuits shown below using ideal diodes, find the values of the voltages and currents indicated. Hint: 5 V is much higher than the junction voltage drop (see 3.3.5).



7. a) At what forward voltage does a diode for which n=2 conduct a current equal to 1000I_s (I_s= saturation current at reverse bias)? b) Expressed in terms of I_s, what current flows in the same diode when its forward voltage is 0.7V?

8. A diode for which the forward voltage drop is 0.7 V at 1.0 mA and for which n=1 is operated at 0.5V. What is the value of the current?

Equivalent circuits

9. Find the Thevenin and Norton equivalent circuits for the circuit shown below. Take care that you orient the polarity of the voltage source and the direction of the current source correctly relative to the terminals a and b.