1. A Si sample is doped with $10^{14}$ boron atoms per cm$^3$.
   (a) What are the carrier concentrations for the Si sample at 300K?
   (b) What are the carrier concentrations at 470K? ($n_i \approx 10^{14}$/cm$^3$ at 470K)?
   (c) What assumptions might have you used?

2. In addition to the conditions in the previous question, the Si band gap is given to be 1.08 eV, and $\frac{m_e^*}{m_{ih}} = 0.71$ at 470K. For both temperature values at 300K and 470K,
   (a) Determine the position of $E_i$.
   (b) Compute $E_F - E_i$.
   (c) Draw an energy band diagram for the Si sample (position horizontal lines labeled with $E_C$, $E_i$, $E_V$ and $E_F$)

3. **Intrinsic Semiconductors & Dopants:**
   Silicon and germanium have the following properties at 300K:
   - Si: $E_g = 1.12$ eV, $N_C (300K) = 6.62 \times 10^{19}$ cm$^{-3}$, $N_V (300K) = 2.51 \times 10^{19}$ cm$^{-3}$
   - Ge: $E_g = 0.66$ eV, $N_C (300K) = 1.02 \times 10^{19}$ cm$^{-3}$, $N_V (300K) = 5.65 \times 10^{18}$ cm$^{-3}$
   A piece of silicon and a piece of germanium are doped with $N_d = 10^{12}$ cm$^{-3}$ antimony (n-type) atoms. **Show quantitatively** that the piece of Si is n-type whereas the piece of Ge is still intrinsic.

4. **Impurity Ionization and Compensation:**
   To a piece of silicon, $N_A = 10^{15}$ cm$^{-3}$ boron atoms and $N_D = 5 \times 10^{15}$ cm$^{-3}$ phosphorus atoms are added. Assume $n_i = 10^{10}$ cm$^{-3}$.
   a. Is the semiconductor p-type or n-type?
   b. Calculate the majority and minority carrier densities at room temperature.
c. Calculate the position of $E_F$ at room temperature.

d. Is the assumption that “all impurity atoms are completely ionized” justified? Show quantitatively for the phosphorus dopant. Assume that for phosphorus, $E_C - E_D = 0.045$ eV.

5. **Mobility and Resistivity:**
Consider a compensated semiconductor (silicon) with dopant concentrations given by $N_D = 10^{17}$ cm$^{-3}$ and $N_A = 9.9 \times 10^{16}$ cm$^{-3}$.

What is the resistivity of the sample? (Use Fig 18 to solve the problem.)

6. Calculate the Fermi level of Si doped with $10^{15}$, $10^{17}$, and $10^{19}$ Phosphorous atoms/cm$^3$ assuming complete ionization. From the calculated Fermi level, check if the assumption of complete ionization is justified for each doping, using any estimated Donor binding energy. (Use the table in the reader).