Problem 1 [8 points]

a) Why is it important to keep track of crystallographic planes and directions within a Si crystal? [2 pts]

Electron and hole mobilities (hence IC device performance) vary with the crystallographic plane and direction of current flow, due to differences in atomic and bond densities.

b) Does the conductivity of intrinsic Si vary significantly with temperature near 300K? Briefly explain your answer. [3 pts]

Yes. Intrinsic carrier concentration increases with $T^{3/2}e^{-Ea/2kT}$ while mobility decreases with $T^{-3/2}$, so their product increases rapidly with increasing temperature.

c) Illustrate thermal generation and donor atom ionization on the energy band diagram [3 pts]
Problem 2 [6 points]
Sketch the electron and hole distributions within the conduction and valence bands, respectively, for a semiconductor with the given density of states and occupancy functions [4 pts]

Is this material n-type or p-type? Justify your answer. [2 pts]

\[ \int_{E_{c}}^{\infty} n(E) \, dE > \int_{-\infty}^{E_{v}} p(E) \, dE \] so \( n > p \)

Problem 3 [11 points]
The energy band diagram for a uniformly doped Si sample maintained at \( T=300K \) is shown below.

a) Is this sample n-type or p-type? [1 pt]

\[ p \text{-type, since } E_{f} < E_{i} \]

b) What are the carrier concentrations \( (n \text{ and } p) \)? [4 pts]
(Remember that \( kT \cdot \ln(10) = 0.060 \text{ eV at } 300K \))

\[ E_{i} - E_{F} = 0.36 \text{ eV} = 6 \times kT \cdot \ln(10) = kT \cdot \ln 10^{6} = kT \ln \left( \frac{p}{n_{i}} \right) \]

\[ \Rightarrow \frac{p}{n_{i}} = 10^{6} \Rightarrow p = 10^{16} \text{ cm}^{-3} \quad n = \frac{n_{i}^{2}}{p} = 10^{4} \text{ cm}^{-3} \]

c) Roughly estimate the resistivity of this sample. [4 pts]

\[ \rho = \frac{1}{\sigma \cdot \mu_{p} \rho} = \frac{1}{(1.6 \times 10^{-19})(450)(10^{16})} = \frac{1}{720 \times 10^{-3}} = 1.4 \Omega \cdot \text{cm} \]

d) Estimate the temperature at which this sample becomes intrinsic. [2 pts]

\[ n_{i} \text{ exceeds } 10 \times 10^{16} \text{ cm}^{-3} \text{ at } T = 800K \]