43. (a) The probability that a state with energy E is occupied is given by

$$P(E) = \frac{1}{e^{(E-E_F)/kT} + 1}$$

where E_F is the Fermi energy, T is the temperature on the Kelvin scale, and k is the Boltzmann constant. If energies are measured from the top of the valence band, then the energy associated with a state at the bottom of the conduction band is $E = 1.11\,\text{eV}$. Furthermore, $kT = (8.62\times10^{-5}\,\text{eV/K})(300\,\text{K}) = 0.02586\,\text{eV}$. For pure silicon, $E_F = 0.555\,\text{eV}$ and $(E-E_F)/kT = (0.555\,\text{eV})/(0.02586\,\text{eV}) = 21.46$. Thus,

$$P(E) = \frac{1}{e^{21.46} + 1} = 4.79 \times 10^{-10} \ .$$

For the doped semiconductor, $(E - E_F)/kT = (0.11\,\text{eV})/(0.02586\,\text{eV}) = 4.254$ and

$$P(E) = \frac{1}{e^{4.254} + 1} = 1.40 \times 10^{-2} \ .$$

(b) The energy of the donor state, relative to the top of the valence band, is $1.11\,\text{eV} - 0.15\,\text{eV} = 0.96\,\text{eV}$. The Fermi energy is $1.11\,\text{eV} - 0.11\,\text{eV} = 1.00\,\text{eV}$. Hence, $(E - E_F)/kT = (0.96\,\text{eV} - 1.00\,\text{eV})/(0.02586\,\text{eV}) = -1.547$ and

$$P(E) = \frac{1}{e^{-1.547} + 1} = 0.824 \ .$$