A semiconductor has a Fermi energy of 0.4 eV. *a*) At 70°F, determine the energy $E_a = E_F + 2.2k_BT$ and the probability that a state at E_a is occupied by an electron (unitless and %). *b*) At 70°F, determine the energy $E_b = E_F - 2.5k_BT$ and the probability that a state at E_b is occupied by a hole (unitless and %).

Convert temperature to Kelvin scale, (70°F − 32) × 5/9 + 273.15 = **294.26111 K**.

a) Compute $2.2k_BT = 2.2\,(8.617333\times10^{-5})\,294.26111 = 0.055786412$ eV.

Therefore, $E_a = E_F + 2.2k_BT = 0.4 + 0.055786412$ $\Rightarrow$ **$\underline{E_a = 0.455786 \text{ eV}}$.**

Use Fermi-Dirac probability function (3.79) to find the probability of an electron at $E = E_a$ as

$$f_F(E = E_a) = \frac{1}{1 + e^{\frac{E_a - E_F}{k_BT}}} = \frac{1}{1 + e^{\frac{0.455786412 - 0.4}{8.617333\times10^{-5}(294.2611)}}}$$

$\Rightarrow$ **$\underline{f_F(E = E_a) = 0.09975049 = 9.97505\%}$.**

b) Compute $2.5k_BT = 2.5\,(8.617333\times10^{-5})\,294.26111 = 0.0633936$ eV.

Therefore, $E_b = E_F - 2.5k_BT = 0.4 - 0.0633936$ $\Rightarrow$ **$\underline{E_b = 0.331535 \text{ eV}}$.**

Per example 3.7, the probability that an energy state is empty (hole) at $E = E_b$ can be found by subtracting the probability of an electron at that energy from 1.

$$f_{\text{hole}}(E = E_b) = 1 - f_F(E = E_b) = 1 - \frac{1}{1 + e^{\frac{E_b - E_F}{k_BT}}} = 1 - \frac{1}{1 + e^{\frac{0.331535 - 0.4}{8.617333\times10^{-5}(294.2611)}}}.$$

$\Rightarrow$ **$\underline{f_{\text{hol\e}}(E = E_b) = 0.06297336 = 6.29734\%}$.**