Exercise 10 - Solution

Task 10.1

1. The Fermi energy E_F is the energy difference between the conduction band and the valence band at 0 Kelvin. An electron in the valence band can jump to the conduction band by gaining an amount of energy equal to E_F.

2. given: $T = 300K$, $E = E_F + 0.1eV$, $k = 8.617343 \cdot 10^{-5} \frac{eV}{K}$

$$f(E) = \frac{1}{1 + e^{\left(\frac{E - E_F}{kT}\right)}} = \frac{1}{1 + e^{\left(\frac{E_F + 0.1eV - E_F}{kT}\right)}} = \frac{1}{1 + e^{\left(\frac{0.1eV}{kT}\right)}} = 0.020468879 \approx 2\%$$

3. given: $T' = 600K$ $E = E_F + 0.1eV$, $k = 8.617343 \cdot 10^{-5} \frac{eV}{K}$

$$f(E) = \frac{1}{1 + e^{\left(\frac{E - E_F}{kT'}\right)}} = \frac{1}{1 + e^{\left(\frac{E_F + 0.1eV - E_F}{kT'}\right)}} = \frac{1}{1 + e^{\left(\frac{0.1eV}{kT'}\right)}} = 0.126299213 \approx 12.6\%$$

The probability, that an energy level E contains an electron, increased. This is due to higher temperature which leads to higher thermal energies of electrons which results in a higher possiblities that electrons make their way through the band gap into the conduction band.

Task 10.2

1. BOL = used to determine the condition of states of the spacecraft over its lifetime in order to take into account that the component experiences degradation

2. EOL = power requirements at end of life are important to guarantee the successful completion of the mission. Oversizing at BOL results in enough power at EOL

1. BOL = conditions of spacecraft component at the beginning of life, EOL = power requirements at end of life.

2. Since solar cells and batteries have limited lifetimes and a performance degradation, the design of a satellite must account for BOL and EOL.

Task 10.3

1.

$$P_{solArr} = \frac{\frac{\text{(power required in eclipse)}\cdot\text{(time in eclipse)}}{\text{path efficiency in eclipse}} + \frac{\text{(power required in daylight)}\cdot\text{(time in daylight)}}{\text{path efficiency in daylight}}}{\text{time in daylight}} =$$

$$= \frac{\frac{100W\cdot 20min}{0.65} + \frac{330W\cdot 68min}{0.85}}{68min} = 438.01W$$

2.

$$P_{BOL} = P_o \cdot I_d \cdot cos(\Theta) = 253\frac{W}{m^2} \cdot 0.77 \cdot cos(23.5°) = 178.65\frac{W}{m^2}$$

3. calculating new I_d:

$$I_d = (1 - 0.0275)^5 = 0.87$$

$$P_{EOL} = P_{BOL} \cdot I_d = 155.4\frac{W}{m^2}$$

4.

$$A_{solArr} = \frac{P_{solArr}}{P_{EOL}} = \frac{438.01W}{155.4W}m^2 = 2.82m^2$$

5.

$$C_{\text{battery}} = \frac{\text{(power required in eclipse)} \cdot \text{(time in eclipse)}}{\text{(depth of discharge)} \cdot \text{(transmission efficiency)}} =$$

$$= \frac{100W \cdot 22min}{0.2 \cdot 0.9} = 203.70Wh$$

convert to Ah:

$$C_{\text{battery}}[Ah] = \frac{C_{\text{battery}}}{U} = \frac{203.70Wh}{27.1V} = 7.52Ah$$