You have probably wondered why solar cells have such a low efficiency. And why should solar cells be made from semiconductors? And why always Silicon (and not, for example, Sodium telluride (TeNa2)) must be? In this statement will we answer (part of) these questions. We will use a toy model for this of what happens in a solar cell.

Semiconductors have a band gap, which means that there is a region of energies, there are not electronic states. Electrons cannot have this energy. Above the band gap is the so-called conduction band, below is the valence band. For semiconductors, the valence band is completely filled, while the conduction band is empty. An electron is excited from the valence band to the conduction band when a solar cell absorbs a photon. Here it will quickly lose its energy until it reaches the bottom of the guide belt ends. Because this excitation occurs locally, there is an energy difference between the regions the size of the band gap. This includes a potential where is the bandgap energy and is the electron charge. This potential can then be used to feed a circuit.

The annoying thing about the light from the sun is that it is not monochromatic, but one spectrum. It meets the approximate spectrum of a black body radiator. In our toy model we will assume that this describes the solar spectrum exactly.

This allows us to immediately identify two problems why no return from 100% can be achieved. Firstly, not all photos have high enough energy to cause an electron to cross the band gap. The energy from this cannot therefore be converted into electrical energy.

1. How much energy is lost as a result? Work out your answer until you are no longer analytical can continue.

Photons with an energy larger than the band gap will not be able to use all energy optimally because a maximum energy of converted into electrical energy.

1. How much energy is lost as a result? Work out your answer again until you stop analytically.
2. How much energy in total is converted into electrical energy. Approach the Planck spectrum with the Wien approach, (this is not really valid in this regime, but the conclusions remain the same in terms of quality).
3. What is the efficiency? Write this as a function of the ratio between and the typical thermal energy .
4. The efficiency has a maximum, this is the Shockley-Queisser limit. Why does the efficiency a maximum? Estimate where this maximum is located and give the associated maximum efficiency.
5. How could you build a solar cell that breaks the Shockley-Queisser limit?
6. Calculate the maximum efficiency. For which bandgap energy is this. Assume 𝑇 = 6000K.

Useful formulas:

Hint: The intensity that a black body radiates per steradian per unit frequency is given by:

Hint: The intensity that a black body radiates per steradian per unit wavelength is given by:

In Wien's approach, the term −1 in both denominations is dropped in the denominator

Hint: A solution of the comparison

is

where