Homework # 1

Solar radiation and de Broglie equation

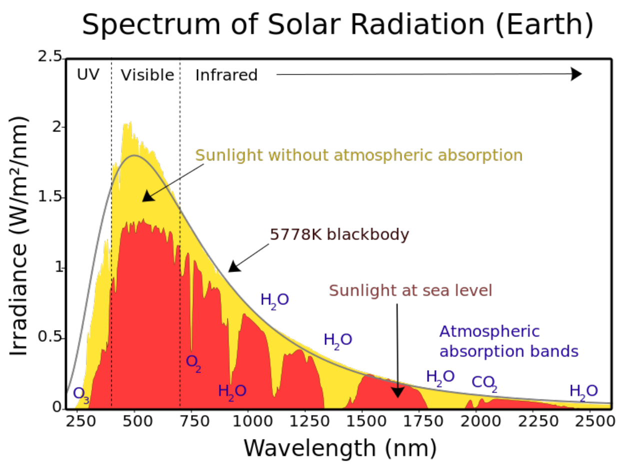

Figure 1: Solar radiation spectrum at the top of the Earth's atmosphere (represented by yellow area) and at sea level (red area). The sunlight has a distribution similar to that of a black body, with a temperature equal to the Sun's surface temperature. Going through the atmosphere, part of light is absorbed by gases while some other undergoes Rayleigh scattering, the latter being responsible for the atmosphere's blue color.

The Sun emits electromagnetic radiation over a large frequency range, peaked in the visible and extending into the UV and infrared regions (see Fig. 1). The solar spectrum can be well approximated with the so-called black-body radiation, which depends only on the body's temperature (here the Sun's surface temperature). Wien's law relates temperature to the wavelength at which the radiation is at maximum, namely:

$$\lambda_{max} = \frac{b}{T} \tag{1}$$

where $b = 2.898 \times 10^{-3} m \cdot K$.

What is the actual color of the Sun? The Sun is essentially all colors mixed together, i.e. it is white! But why do we see the Sun as yellow during the day, and orange or redish during the sunset? This is because of the light scattering in the Earth's atmosphere (light is scattered more in the blue while it is scattered less in yellow and red). Actually, the Sun's spectrum is peaked in the green ($495 - 570$ nm), see Figure 1.

1. Use Wien's law to estimate the temperature of the Sun's surface.

2. Can we use green (or any other visibile) light to probe the atomistic structure of materials, where typical distances are of the order of few angstroms?

The ozone layer is a region of Earth's stratosphere that absorbs a substantial part of the Sun's ultraviolet (UV) radiation, especially in the UV-C range ($100 - 280$ nm) which is very harmful to all living beings.

3. What is the energy of a UV-C photon?
(*Hint: in the following you may need the Plack constant* $h = 6.626 \times 10^{-34}\ J \cdot s$.)

4. What is the minimum energy a photon must have in order to resolve the atomistic structure of materials? What kind of photon is that (IR, UV, ...)?

5. How hot should a black body be, in order to have a spectrum peaked at wavelenghts such to resolve the atomistic structure?

Suppose now we want to use neutrons instead of photons. In the following consider neutrons (mass $m_n = 1.675 \times 10^{-27}$ Kg) as classical particles with a kinetic energy $E = \frac{3}{2}k_B T$, where T is the temperature and $k_B = 1.38 \times 10^{-23}\ J/K$ the Boltzmann constant.

6. What is the minimum energy and velocity that neutrons should have in order to resolve atoms?
(*Hint: Use de Broglie equation.*)

7. What is their corresponding temperature?

8. Finally, we want to use electrons (mass $m_e = 9.11 \times 10^{-31}$ Kg) instead of neutrons. Which is the minimum energy, velocity and corresponding temperature that electrons should have in order to resolve the atomistic structure of materials?