Exercises for T2, Summer term 2017, Sheet 1

Hint: The numerical values of the physical constants that are needed in the first exercises can be found on the webpage pdg.lbl.gov → Reviews, Tables, Plots → Constants, Units, Atomic and Nuclear Properties → Physical Constants. Make sure you use the units consistently.

1) Energy of photons of visible light
The wavelength of visible light is between 360 nm (violet) and 780 nm (red). Calculate the corresponding photon energy in electronvolt (eV). Compare your results with the ionization energy of a hydrogen atom, also called Rydberg energy.

2) Spatial resolution
The spatial resolution of a traditional light microscope is limited by the wavelength of visible light. For this reason a light microscope can be used to see bacteria ($\sim 10^{-6}$m), but not viruses ($\sim 10^{-7}$m). Calculate the energy of the photons in eV that is needed to resolve crystal structures (typical atomic distances $\sim 10^{-10}$m=1$\AA$). Which kind of radiation does this energy of the photons correspond to?

3) De Broglie wavelength of ultra-relativistic particles
The relation between the de Broglie wavelength λ and the energy E used in the exercises above is not only valid for photons, but for any ultra-relativistic particle ($v \simeq c$). A particle is called ultra-relativistic if its energy is much greater than its rest energy ($E \gg mc^2$, where m is the rest mass). What is the minimum energy in eV that such a particle needs to have in order to get some information about the structure of an atomic nucleus ($R_{\text{nucleus}} \sim 1.2\,\text{fm}\,\text{A}^{1/3}$, A = number of nucleons in the nucleus)? Compare to the mass energy in eV of a proton at rest. What distances can be resolved in experiments with electrons with 100 GeV?

4) Economical light source
In the lecture the spectrum of black-body radiation was disussed as a function of frequency ν and temperature T. Find the temperature T_{opt} at which the the fraction of energy that is radiated as visible light has its maximum value. Find that fraction with an accuracy of one percent. You can evaluate the integrals that you need to solve (and that you should write down in your solution explicitly) numerically, e.g. with Mathematica or Maple, and then solve for the temperature T_{opt} numerically/graphically with an accuracy of 1 Kelvin. Compare your results with the temperature at the surface of the sun and with the temperature of the glowing filament of usual light bulb.