Experimental Physics III

Submission due: January 26, 2023, before the lecture starts

Exercise Sheet 12

12.1

As we measured in the lecture, the projector without IR filter emits a spectrum similar to a black body.

- Calculate an expression that correlates the wavelength λ_m at which the spectral energy density $\omega_\lambda(\lambda, T)$ peaks and compare this relation to Wien's displacement law. Hint: Substitute $\lambda \cdot T =: \Lambda$ and use the root as graphically determined in Figure 1 (left).

- During the lecture we also measured the values of the peak wavelength of the radiation for three different values of voltages and thus for three different temperatures. These values are 3.620 µm, 2.900 µm, and 2.070 µm (Figure 1 (right)). Calculate the corresponding values of the temperature of the detector lamp's filament.

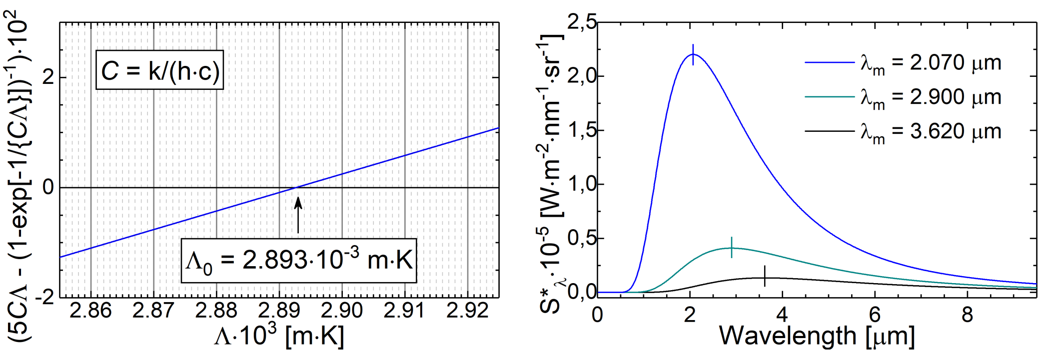

Figure 1: (left) Graphically determined root of the function as stated on the y-axis. (right) Spectral radiance as measured during the lecture and indicated peaks of the curves.

12.2

An X-ray quantum with a wavelength of $\lambda = 1$ Å interacts with a weakly bound electron of an atom and is deflected by an angle of $\theta = 90°$. Calculate the energy absorbed by the electron during this process and the moving direction of the electron afterwards.

12.3

- A sphere with a mass of 40 g flies with a speed of 1000 m/s. Although the sphere is obviously too large to be described as a matter wave, calculate its de Broglie wavelength.

- Imagine you are playing soccer in another universe where Planck's constant has the value 0.60 Js. Calculate the uncertainty the 0.50 kg soccer ball would have if its speed had been 20 m/s with an uncertainty of 1.0 m/s (flying along a fixed axis).

- During the transition from the first excited state of a hydrogen atom into the ground state, photons with a wavelength of 121.5 nm are emitted. The life time of the excited state is 10 ns. Calculate the natural line broadening of the excited state using the energy uncertainty.

12.4

Calculate the reflection probability of a particle with a kinetic energy of $E_{\text{kin}} = 4$ eV at a negative potential step of height $E_0 = -12$ eV starting from the time-independent Schrödinger equation.

12.5

A bound electron–positron pair is known as positronium. The positron is the antiparticle of the electron with charge $+e$ and the same rest mass as the electron. By considering that e^- and e^+ are orbiting the mutual center of mass, derive and calculate the following quantities:

- the formula and the value of the corresponding Bohr radius with $n = 1$,
- the binding energy of the system,
- the energy and the wavelength of a photon which is emitted if the electron returns from state $n = 2$ back to the ground state.