Quantum Physics – Homework 3

Due Thursday 2$^{\text{nd}}$ February at 4. Attempt answers to all questions.

Hand in your script by the deadline into the post box near the secretaries' offices on level 1. **Assignments handed in past the deadline will not be marked.** Course title, week number and student name should appear on every sheet of the worked exercises, which should be securely bound together. Please *also* write your tutor's initials and time of tutorial on the cover sheet.

Problem 1 `[30 marks]`

Planck's formula for the spectral emittance of a blackbody is

$$R(\lambda, T) = \frac{2\pi hc^2}{\lambda^5} \frac{1}{e^{\frac{hc}{\lambda kT}} - 1} ,$$

where T is the temperature, λ is the wavelength of the radiation emitted.

(i) Calculate the total power emitted per unit area (or total emittance) $R := \int_0^\infty d\lambda\, R(\lambda, T)$ and show that the result is of the form $R \sim T^4$. Find the numerical value of the proportionality constant between R and T^4 and compare it to the Stefan-Boltzmann law, thereby finding a prediction for Stefan's constant σ. You will need to use

$$\int_0^\infty dx \frac{x^3}{e^x - 1} = \frac{\pi^4}{15} .$$

[12]

(ii) Find the position λ_{max} of the maximum of $R(\lambda, T)$, and check that Wien's displacement law is satisfied. **[12]**

(iii) A certain star emits radiation mainly in the infrared with wavelength of 900 nm, while a second star radiates principally at a shorter wavelength of 600 nm. Use Wien's law to calculate the ratio between the temperatures of the two stars. **[6]**

Problem 2 `[20 marks]`

The threshold wavelength in order to eject photoelectrons from the surface of the metal lanthanum is 376 nm.

(i) Find the work function (in eV). **[7]**

(ii) Determine the maximum kinetic energy of the photoelectrons and the stopping potential if the metal is illuminated with light of wavelength $\lambda = 200$nm. **[8]**

(iii) What happens if the metal is illuminated with light of wavelength 400 nm? **[5]**