Z11 - Checking the Stefan-Boltzmann Formula and Determination of the C_2 Constant Appearing in the Plack's Law

Physics Laboratory II
Faculty of Physics, Astronomy and Applied Computer Science, Jagiellonian University

The purpose of the experiment is understanding laws describing the black body radiation and finding the exponent in the Stefan-Boltzmann formula for total radiated power as well as determination of the Planck constant value h.

Preparatory questions

1. Definitions of the parameters used to describe the radiation, the concept of the black body [1].
2. Basic laws describing the phenomenon of black body radiation: Stefan-Boltzmann law, Planck law [1].
3. The dependence of electrical resistance on the temperature for normally conductive metal [1].
4. Principles of operation and construction of used measuring instruments [1].

Computational assignments

1. 1. Find the relationship between the power spectral density of an isotropic radiation field $\rho_T(\nu)$ and the spectral density of the energy flux $R(\nu)$ [the power flowing in one direction through a unit area in this field]. One should get the result: $R(\nu) = \frac{c}{4}\rho_T(\nu)A(\nu)$.
2. 2. Calculate the spectral mode density $\frac{dN(\nu)}{d\nu}$ of the macroscopic radiation field.

Apparatus and materials

Experimental set-up consists of:

- Incandescent lamp.
- Monochromator with photomultiplier.
- Hg spectral lamp for calibrating the wavelength scale of the monochromator.
- Reference resistance, digital voltmeters.
- Optical pyrometer with disappearing filament.

Experiment

Part I: finding the exponent in the Stefan-Boltzmann formula for total radiated power.

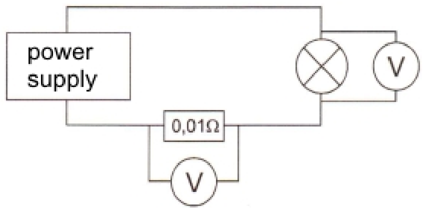

Figure 1: A scheme of an apparatus for determining of the exponent in the Stefan-Boltzmann formula.

1. Set up the apparatus as in Fig. 1.
2. Record voltages on the bulb and on the resistance in a wide range of supply voltage (0-5V).
3. Plot the dependence of the total power of the bulb vs. its resistance.
4. Identify the temperature range (bulb resistance) in which we can neglect the radiation losses.
5. Fit the straight line in this range and extrapolate it to the whole measured range, thereby obtaining the power lost by the bulb due to the thermal conductivity of the system.
6. Subtract the power lost by the bulb due to the thermal conductivity of the system from the total power to obtain the radiated power as a function of resistance (temperature).
7. Fit the radiated power of the bulb by the appropriate function.

Part II: determination of the h/k coefficient in the Planck formula.

1. Set up the apparatus as shown in Fig. 2 but use the spectral lamp standard instead of the bulb.
2. Read the positions of spectral lines of the spectral lamp by tuning the SPM2 monochromator and identify the lines to find their wavelengths. Make a dispersion curve (calibrate the monochromator).
3. Set up the apparatus in Fig. 2.

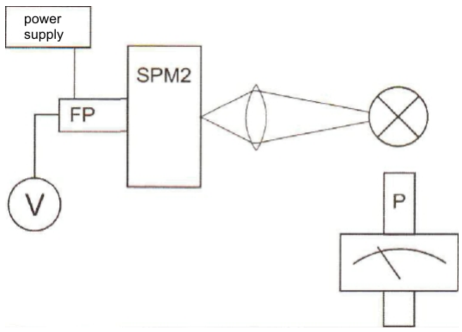

Figure 2: A scheme of an apparatus for determining the coefficient in the Planck formula. FP -photomultiplier, SPM2 -monochromator, P pyrometer.

4. For three different wavelengths (eg corresponding to red, yellow and blue light), measure the spectral density of the radiation flux as a function of the temperature of the light bulb filament (isochromats).

5. Fit the appropriate functions to the obtained data and read the constant h/k.

Data analysis

The report should include the following graphs:

1. Dependence of the total power of the bulb from vs. the bulb resistance.

2. Enlarged portion of the plot where the power depends linearly on the resistance along with the fitted linear relationship.

3. Power radiated from the bulb and the function fitted.

4. Monochromator dispersion curve.

5. The dependence of the voltage on the photomultiplier (the measure of the spectral density of the radiation flux) on the bulb filament temperature for several selected wavelengths together with the model functions fitted.

Safety rules

The photomultiplier is powered by a high voltage over 1 kV. Do not open the photomultiplier case or power supply unit when the voltage is on. The Mercury spectral lamp may emit harmful ultraviolet light. Avoid looking directly to the light source !

References

[1] Script/extended instruction: *Wyznaczanie stałej C_2 we wzorze Plancka i sprawdzanie prawa Stefana-Boltzmanna.*