Exercise 31	Verification of Stefan-Boltzmann's law

Measurement procedure

1. Equipment

- RT type temperature regulator with temperature sensor, heater representing a black body, and mechanical modulator of infrared radiation flux,
- Pyroelectric detector of infrared radiation,

2. Goals

In this exercise the main goal is to determine an exponent in the Stefan-Boltzmann's law. In order to do this a radiation intensity of a heater (representing a black body) is measured as a function of temperature.

3. Measurement setup

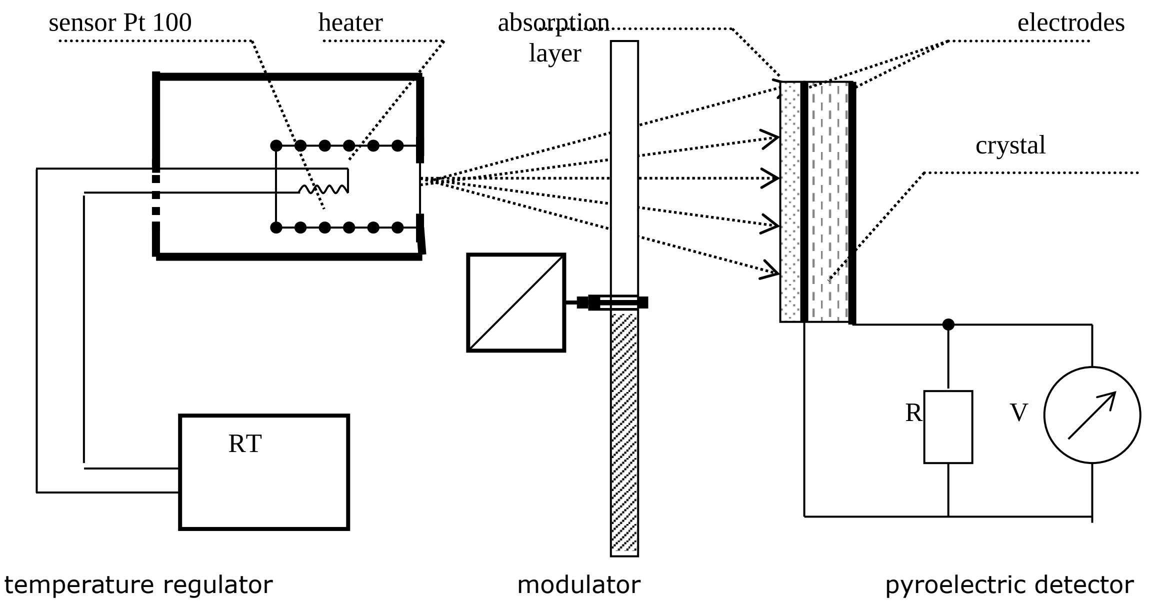

Fig.1. A diagram of the measurement setup. Three main modules are distinguished: a temperature regulator with a black body heater, a mechanical modulator of infrared radiation flux, and a pyroelectric detector

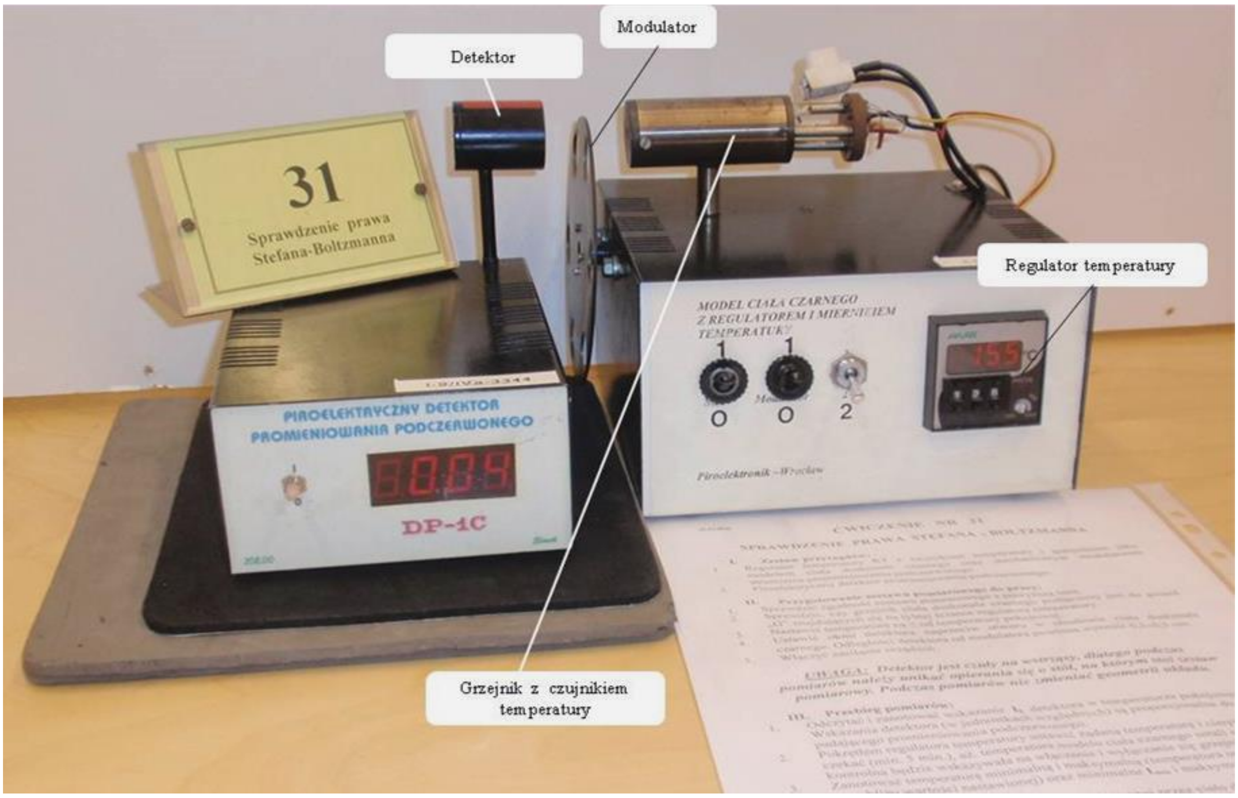

Fig.2. An exemplary setup

4. Measurement procedure

Preparation of the measurement setup:

- Check whether all necessary equipment is available in the laboratory (compare with the list provided above);
- Check whether the black body heater is plugged into "G" type sockets, which are located on the back of the temperature regulator;
- Make sure that the temperature selected on the regulator is lower than the room temperature;
- Place the pyroelectric detector in front of an opening in the box of the heater (representing a black body). The distance between the heater and the mechanical modulator of an infrared radiation flux should be approximately 0.3-0.5 cm;
- Switch on the devices (ask a supervisor to check your setup first),

Measurements:

- Read and write down the room temperature radiation intensity, I_0. The value displayed on the detector is proportional to the power of an infrared radiation;
- Use the regulator's knob to set the temperature to 250 degrees (at least). Wait approximately 5 minutes until the temperature of a black body is established. Note that there is an indicator light which signals when the heater is working;
- Read and write down the established temperature at least five times (it is displayed by the temperature sensor, and it should slightly fluctuate near the value selected with a knob). Simultaneously, read and write down intensities displayed by the pyroelectric detector;
- Conduct measurements of the power emitted by the black body in temperatures ranging from 250 degrees to 550 degrees (repeat the steps from the previous point). Each time increase the temperature by no more than 25-30 degrees. Furthermore, while

investigating temperatures lower than 350 degrees, the power switch should be in the position **1**, while when investigating equal and higher temperatures – in the position **2**;

5. Calculations & data analysis

- Prepare $I(T)$ and $I(T^4)$ plots. Assume that $I = \bar{I} - I_0$ (where $\bar{I}$ is an average intensity measured in the constant temperature selected by the regulator's knob) and $T = \bar{T}[K]$ (where $\bar{T}$ is an average temperature in kelvins displayed by the temperature sensor in the constant temperature selected with the regulator's knob). Indicate uncertainties for several points in low-temperature, average-temperature, and high-temperature ranges of plots. Discuss the results;
- Prepare a $\ln I\,(\ln T)$ plot. Calculate the slope, a, and correlation factor, R, of the linear part of the plot. The slope, a, should be equal to the exponent from the Stefan-Boltzmann's law. Discuss the results. Add a best-fit linear function to the plot and compare it with the plot from the previous point;

6. Additional information

<u>WARNING!</u> The *detector is a very sensitive device. Hence, during the measurements, it is not allowed to lean on a table with a setup (or touch it incautiously). Furthermore, the geometry of a setup cannot be changed when the experiment is being conducted.*

In this exercise a black body is heated up to high temperatures. Be cautious and avoid touching the device.

7. Exemplary tables

Table 1. Temperatures of the black body heater, and corresponding intensities of an infrared radiation (Protocol).

lp.	$\boldsymbol{T_0}[°C]$	$\boldsymbol{I_0}$ [a. u.]
1		
2		
3		
⋮		
n		

lp.	$\boldsymbol{T_1}[°C]$	$\boldsymbol{I_1}$ [a. u.]
1		
2		
3		
⋮		
n		

lp.	$\boldsymbol{T_2}[°C]$	$\boldsymbol{I_2}$ [a. u.]
1		
2		
3		
⋮		
n		

…

Table 2. Intensities of an infrared radiation as a function of a temperature (Report).

lp.	$\boldsymbol{T_0}[°C]$	$\boldsymbol{T_0}[K]$	$\boldsymbol{I_0}$ [a. u.]	$\boldsymbol{\bar{T}}[K]$	$\boldsymbol{\bar{T}^4}[K^4]$	$\boldsymbol{I = \bar{I} - I_0}$
1						
2						
3						
⋮						
n						
$\bar{X}$						
ΔX						
$u(X)$						
$u_c(X)$						

lp.	$\boldsymbol{T_1}$[°C]	$\boldsymbol{T_1}$[K]	$\boldsymbol{I_1}$ [$a.u.$]			
1						
2						
3						
⋮						
n						
$\bar{X}$						
ΔX						
$u(X)$						
$u_c(X)$						
lp.	$\boldsymbol{T_2}$[°C]	$\boldsymbol{T_2}$[K]	$\boldsymbol{I_1}$ [$a.u.$]			
⋮	⋮	⋮	⋮	⋮	⋮	⋮

Include the calculated exponent from the Stefan-Boltzmann's law and its uncertainty below the table.