EXPERIMENT 1

STEFAN BOLTZMANN'S RADIATION LAW

AIM: Stefan Boltzmann's radiation Law describes the total emission of a black-body radiator. It states that the total radiation energy emitted by a black body into the space in front of it's opening per unit time is proportional to the fourth power of its temperature. This relationship is experimentally verified.

APPARATUS: 1 small optical bench, 1 Moll's thermocouple, 1 microvoltmeter, 1 tube oven, tube oven table, 1 Temperature sensor,
, 1 large stand base, 4 Leybold multiclamps.

METHODOLOGY:

SURROUNDINGS

Cavity

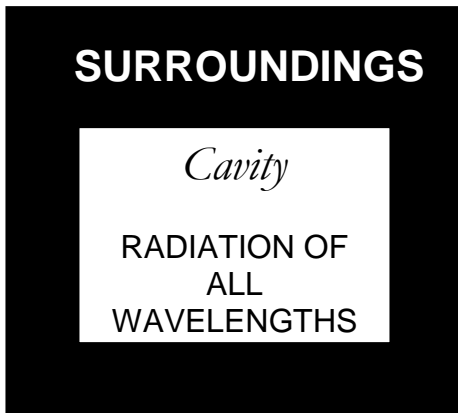RADIATION OF
ALL
WAVELENGTHS

Figure 1.1. A blackbody

A blackbody absorbs all radiation incident on it. We picture it as a cavity in an enclosure where the temperature is uniform and constant.
A blackbody must be in **thermal equilibrium**, emitting and absorbing radiation at the same rate with it's surroundings.

In the laboratory we will approximate it as in Figure 1.2. with a hole letting out a sample of radiation to study

Figure 1.2. An approximation
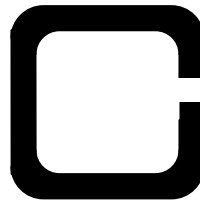
According to the Stefan Boltzmann Law for a blackbody, the total energy emitted per second (power P) increases rapidly with temperature. It has been shown that the following relationship holds:

$$P = \sigma \mathrm{A} T^4 \qquad (1.1)$$

where T is the absolute temperature in Kelvin, A the surface area of the body and $\sigma = 5.6696 \times 10^{-8} Wm^{-2}K^{-4}$ is the Stefan-Boltzmann constant.

In this experiment the above relationship is verified. The blackened inner walls of an electrically heated tube are used as a black-body. The emitted radiation will be measured using a thermocouple.
A pinhole diaphragm, between the oven and the thermocouple restricts the view of the thermocouple to the radiating surface of the tube oven and screens environmental stray radiation (oven walls).
If the temperature of the thermocouple was absolute zero, its output voltage would be proportional to the incident radiation energy per unit of time as in (1.1).
However as it is at room temperature we have to take it into account, such that:

$$V \sim T^4 - T_o^{\ 4} \qquad (1.2)$$

Where V is the output voltage of the thermocouple, T the temperature of the radiator and T_o, the room temperature. Finally V is plotted against $\left(T^4 - T_0^{\ 4} \right)$.
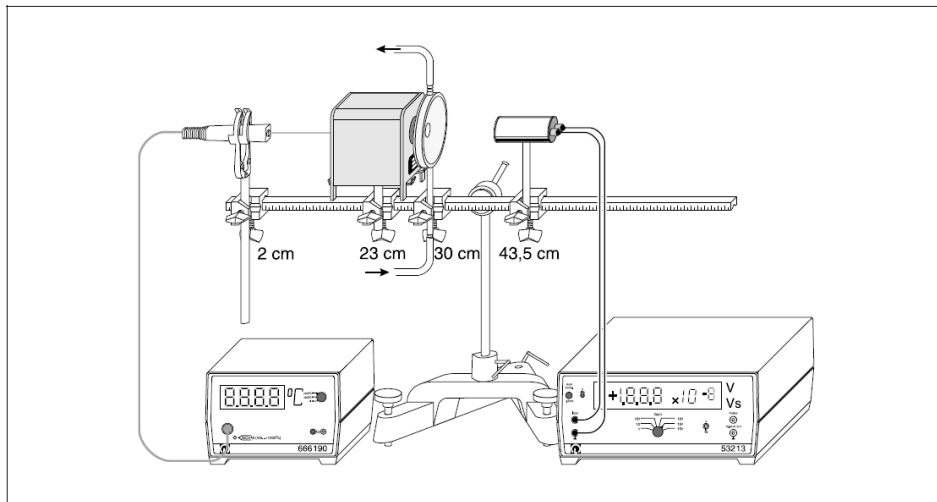
PROCEDURE:

Figure 1.3: Experiment setup and electrical connections. In brackets: positions of the clamps (left clamp edge) on the optical bench.
(1) Temperature sensor, (2) oven, (3) Diaphragm, (4) Moll's thermocouple(the thermopile).

Experiment setup:

1. Make the necessary connections with regards to your experimental set up as in Figure 1.3 and take the room temperature.

   Note: the glass window absorbs long-wave radiation more than short-wave radiation, and thus systematically falsifies the temperature-dependent measurement of radiant intensity.

2. Insert the temperature probe half-way through the oven and then turn on the mains supply.
3. Remove the glass window of the thermopile.
4. Mount the temperature sensor in place with the universal clamp S and switch on the digital thermometer (measuring range $> 200\ ^oC$).
5. Align the openings of the electric oven, the screen of the black body accessory and the thermopile so that the radiant
6. Heat is directly incident on the opening of the thermopile.
7. Connect the thermopile to the microvoltmeter as shown in Fig. 1 (measuring range 10–4 V); make sure the red socket on the thermopile is connected to the red socket on the microvoltmeter.
8. Compensate the offset by pressing the key "auto comp"; if necessary, carry out the fine adjustment using the potentiometer to set the digital display to zero (see Instruction Sheet for the microvoltmeter).
9. Attach the silicone tubing to the immersion pump and the screen so that the inflow is at the bottom hose nipple and the outflow is at the top hose nipple of the screen.
10. Fill the water vessel with water and attach the immersion pump to the rim of the water vessel e.g. using the mounting clamp so that the inlet opening is completely submerged and the maximum immersion depth of 17 cm is not exceeded (see Figure 1.4).
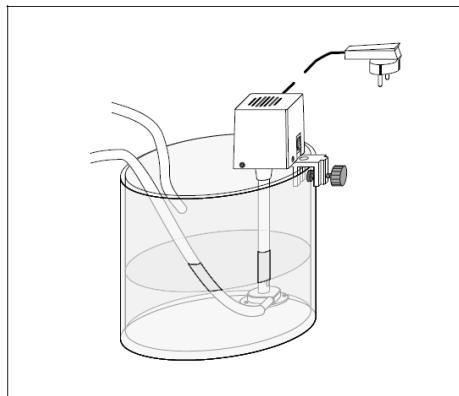

Figure 1.4: Setup example for mounting the immersion pump on the water vessel

Carrying out the experiment

1- Measure the temperature T of the brass cylinder and the initial output voltage U of the thermopile and write these values in your experiment log.
2- Switch on the electric oven; for each temperature increase of 25^oC, write the measured values T and U in your experiment log.
3- When the temperature reaches a level between 400^oC and $500\ ^oC$, Switch off the electric oven; for each temperature decrease of 25^oC, write the measured values T and U in your experiment log.

4- When the temperature reaches a level between 100°C and room temperature, remove the temperature sensor from the electric oven, measure the room temperature and write this value in your experiment log.
5- Screen the thermopile with dark cardboard, check the zero point of the voltmeter and write this value in your experiment log.
6- Graph the results and find the slope

RESULTS TABLE   **(To=……………….K)**

T (^{O}C)	T (K)	T^4 (K)	T^4 –T$_0^4$ (K^4)	V (nvolt)
100				
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.				
400-500	.	.	.	.

SAFETY NOTE:

- **Do not change the position of the apparatus or your own position when recording the measurement series so that your own body heat does not influence the thermocouple.**
- **Danger of burns: the outer wall of the electric oven can exceed 200 oC.**
- **Avoid burning your skin on the hot electric oven.**
- **Only operate the electric oven on its support.**
- **Read the Instruction Sheet for the electric oven carefully,**
- **and observe all instructions.**