LESLIE CUBE

EXPERIMENT PROCEDURE

- **Detect radiation from a Leslie cube with a Moll thermopile.**
- **Measure intensity of heat radiated by four different surfaces in relation to one another as a function of temperature.**
- **Confirm that the radiation intensities are proportional to T^4.**

OBJECTIVE

Measure the heat radiated by a Leslie cube.

SUMMARY

The radiation emitted by a body depends on its temperature and the nature of its surface. More specifically, according to Kirchhoff's law, the ratio between emissivity and absorptivity is identical for all bodies at a given temperature and corresponds to emissivity of a black body E_{SB} at this temperature. In this experiment, we will heat a Leslie cube by filling it with water to a temperature of 100°C and ascertain the radiated intensity in a relative measurement using a Moll thermopile.

REQUIRED APPARATUS

Quantity	Description	Number
1	Leslie's Cube	1000835
1	Rotating base for Leslie cube	1017875
1	Moll-Type Thermopile	1000824
1	Measurement Amplifier (230 V, 50/60 Hz)	1001022 or
	Measurement Amplifier (115 V, 50/60 Hz)	1001021
1	Digital Multimeter P3340	1002785
1	Digital Quick Response Pocket Thermometer	1002803
1	K-Type NiCr-Ni Immersion Sensor, -65°C – 550°C	1002804
1	Pair of Safety Experiment Leads, 75 cm	1002849
1	HF Patch Cord, BNC/4 mm Plug	1002748
2	Barrel Foot, 500 g	1001046
1	Pocket Measuring Tape, 2 m	1002603

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BASIC PRINCIPLES

Heat is exchanged between a body and its surroundings by the emission and absorption of heat radiation. The radiation depends on the body's temperature and the nature of its surface, as can be demonstrated by means of a Leslie cube.

The emitted intensity is described by the body's emissivity *E*. The absorptivity *A* is the ratio between absorbed and incident radiation intensity. It turns out that absorptivity increases with emissivity. More specifically, according to Kirchhoff's law, the ratio between emissivity and absorptivity is identical for all bodies at a given temperature, and corresponds to emissivity of a black body E_{SB} at this temperature:

(1) $$\frac{E(T)}{A} = E_{SB}(T) = \sigma \cdot T^4$$

σ: Stefan-Boltzmann constant
T: Temperature in Kelvin

The degree to which absorptivity depends on temperature is generally negligible. Therefore the emissivity of a body can be described as follows:

(2) $$E(T) = A \cdot \sigma \cdot T^4$$

If the body has the same temperature T_0 as its surroundings, the intensity of the heat radiated by the body into the surroundings is equal to that of the heat it absorbs from them:

(3) $$E(T_0) = A \cdot \sigma \cdot T_0^4$$

If the body's temperature is higher, the intensity of the radiation absorbed from the surroundings does not change as long as the ambient temperature remains constant. Therefore, the energy radiated by a body per unit of surface and time and measurable by means of a radiation detector is as follows:

(4) $$\Delta E(T) = A \cdot \sigma \cdot \left(T^4 - T_0^4\right)$$

In this experiment, a Leslie cube equipped with one white, one black, one matt and one shiny surface is heated by filling it with water boiled to a temperature of 100°C. The radiated intensity is then ascertained by means of a relative measurement using a Moll thermopile. The measured values for the four different surfaces are monitored during the entire process of cooling to room temperature.

EVALUATION

Plotting the readings against the quantity $x = T^4 - T_0^4$ results in four lines which pass through the origin and have slopes corresponding to the respective absorptivities of the surfaces.

In the investigated temperature range up to 100°C, there is no great difference between the black and white surfaces or between the matte and glossy surfaces, even though the visual distinction is clear. Obviously, the surfaces do not differ significantly in the infra-red wavelength range.

1: White surface. 2: Black surface. 3: Matt surface. 4: Shiny surface.

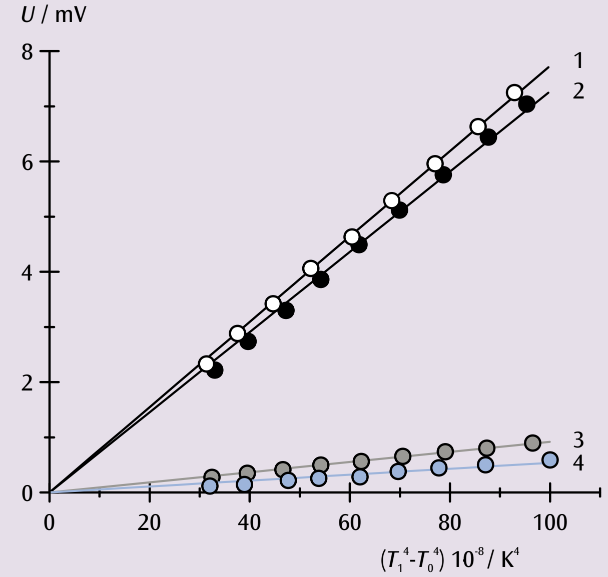

Fig 1: Radiated intensity from a Leslie cube as a function of $x = T^4 - T_0^4$