Experiment 243: The Stefan-Boltzmann and Inverse square laws

Aim

The purpose of this experiment is to confirm the inverse square and Stefan-Boltzmann laws of radiation.

Part I: The inverse square law

As one moves away from a point source of radiation such as a star, the intensity reduces by $1/(\text{distance})^2$. This section of the laboratory demonstrates this dependence for thermal radiation.

Procedure

(1) Adjust the height of the Radiation Sensor so it is at the same level as the filament of the Stefan-Boltzmann lamp. Orient the bulb so that the radiation sensor "sees" the entire filament. Connect the sensor to the multimeter and the lamp to the power supply.

(2) With the lamp OFF, slide the sensor along the meter stick. Record the reading of the voltmeter at 10 cm intervals. Average these values to determine the ambient level of thermal radiation . You will need to subtract this average ambient value from your measurements with the lamp ON, in order to determine the contribution from the lamp alone.

(3) Turn on the power supply to illuminate the lamp. Set the voltage to approximately 11 V (**Do not let the voltage of the lamp exceed 12 V**).

(4) Adjust the distance between the sensor and the lamp filament to several different settings and record the sensor readout. Use separations (in cm) of 50, 40, 30, 25, 20, 18, 16, 14, 12, 10, 9 and 8. Make measurements quickly and place the reflect heat shield between the lamp and sensor between measurements otherwise heating of the sensor will distort results.

(5) For each value of separation (x), calculate $1/x^2$.

(6) Adjust your results to account for the ambient thermal radiation.

(7) Plot the radiation level versus distance from the source. Include only those points for which the radiation level was greater than about 1 mV, since readings smaller than this are subject to large fractional uncertainty.

(8) Plot the radiation level versus $1/x^2$, including error bars.

Questions (to be addressed in your report)

1. Which of the two plots is linear? Is it linear over the entire range of measurements, within experimental uncertainties?
2. The inverse square law states that the radiant energy per unit area emitted by a point source of radiation decreases as the square of the distance from the source to the point of detection. Do your data support this assertion?
3. Is the Stefan-Boltzmann lamp truly a point source of radiation? If not, how might this affect your results? Do you see such an effect in the data you have taken?

Part II: The Stefan-Boltzmann law

The Stefan-Boltzmann Law states that the intensity of the radiation from a black body (such as most stars to a reasonable degree of approximation) increases as T^4 for increasing temperature. In this experiment you will make relative measurements of the power per unit area emitted from a hot object, in particular, the Stefan-Boltzmann lamp, at various temperatures. From your data you will be able to test the dependence of the radiated power on temperature.

Procedure

(9) Before turning on the lamp, measure T_{ref}, the room temperature in degrees Kelvin and R_{ref}, the resistance of the filament of the Stefan-Boltzmann lamp at room temperature.

(10) Set up the experiment with the front face of the sensor approximately 6 cm away from the filament. The entrance angle of the thermal radiation detector should only contain the filament.

(11) Turn on the power supply. Set the voltage approximately to each of the following settings (1.00, 2.00, 3.00, 4.00, 5.00, 6.00, 7.00, 8.00, 9.00, 10.00, 11.00, and 12.00 Volts). For each setting, record the voltage across the filament, the current through the filament, and the output from the radiation detector.

(12) Calculate the resistance of the filament at each of the voltage settings used.

(13) Use the table below to determine the temperature of the filament.

$R/R_{300\,\text{K}}$	Temperature [K]	$R/R_{300\,\text{K}}$	Temperature [K]
1.00	300	10.03	2000
1.43	400	10.63	2100
1.87	500	11.24	2200
2.34	600	11.84	2300
2.85	700	12.46	2400
3.36	800	13.08	2500
3.88	900	13.72	2600
4.41	1000	14.34	2700
4.95	1100	14.99	2800
5.48	1200	15.63	2900
6.03	1300	16.29	3000
6.58	1400	16.95	3100
7.14	1500	17.62	3200
7.71	1600	18.28	3300
8.28	1700	18.97	3400
8.86	1800	19.66	3500
9.44	1900	26.35	3600

(14) Graphically verify the Stephan-Boltzmann Law, including allowance for errors.

Questions (to be addressed in your report)

4. What is the relationship between the measured radiation and T? Does this hold over the entire range of measurements within experimental uncertainties?
5. The Stefan-Boltzmann Law is perfectly true only for ideal, blackbody radiation. Is the filament a good approximation of a black body?

List of Equipment

(Located in the interior room in the stage 1 physics laboratory)

1. Multimeter
2. Power Supply
3. Stefan-Boltzman lamp
4. IR Radiation Sensor
5. Meter Stick

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