Experiment: Thermal Radiation

Equipment:
Thermal radiation cube
2 Multimeter
Stefan-Boltzman lamp
IR Radiation Sensor
Meter Stick / Tape

Purpose: The purpose of this experiment is to discover general properties of radiation and to confirm the Stephan-Boltzmann Law.

Write-Up: Include a general introduction with the purpose of the lab and a summary for each of the three parts. Address the questions in full sentences.

Part I: Radiation Rates and emissivities of different surfaces

The cube furnace has four qualitatively different surfaces (black, white, polished aluminum and dull aluminum). Each one of these surfaces radiates energy differently or at a different rate. The following procedure is designed such that you will determine which surface has the maximum thermal emissivity.

1. Connect the Ohmmeter to the thermometer on the cube furnace and digital voltmeter to the radiation sensor.

2. Turn on the furnace to "high". When the temperature sensor reading is roughly 40,000ohms, reset the power switch to 5.0.

3. When the cube reaches thermal equilibrium (resistance of the temperature sensor is reasonably constant), use the radiation sensor to measure the radiation emitted from each of the four surfaces of the cube. Place the sensor so that the posts on its end are in contact with the cube surface. This ensures a constant distance from the surface for each of the measurements. Record the temperature and the uncertainty in temperature.

Address the following questions in your summary:

1. List the surfaces of the cube furnace in order of the amount of radiation emitted.

2. It is a general rule that good absorbers of radiation are also good emitters. Are your measurements consistent with this rule?

3. Do different objects, at approximately the same temperature, emit different amounts of radiation?

P**art II.** Inverse square Law

As one moves away from a point source of radiation, the intensity reduces by 1/(distance)^2. This section of the laboratory demonstrates this dependence for thermal radiation.

1. Experimental Setup
    a. Tape a meter stick to the table.

    b. Place the Stefan-Boltzmann Lamp at one end of the meter stick. The zero point of the meter stick should align with the center of the lamp filament.

    c. Adjust the height of the Radiation Sensor so it is at the same level as the filament of the Stefan-Boltzmann Lamp.

    d. Align the lamp and sensor so that, as you slide the sensor along the meter stick, the axis of the lamp aligns as closely as possible with the axis of the sensor.

    e. Connect the sensor to the voltmeter and the lamp the the power supply.

2. With the lamp OFF, slide the sensor along the meter stick. Record the reading of the voltmeter at 10cm 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. Record the resistance of the filament of the lamp. (be very accurate here)

4. Turn on the power supply to illuminate the lamp. Set the voltage to approximately 10V. (Do not let the voltage of the lamp exceed 13V)

5. Adjust the distance between the sensor and the lamp filament to several different settings and record the sensor readout. Use separations of (in cm) 2.5, 3.0, 4.0, 4.5, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0, 12.0, 14.0, 16.0, 18.0, 20.0, 25.0, 30.0, 35.0, 40.0, 45.0, 50.0, 60.0, 70.0, 80.0, 90.0, and 100.0. (make measurements quickly and place the reflect heat shield between the lamp and sensor between measurements otherwise heating of the sensor will distort results).

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

7. Adjust your results to account for the ambient thermal radiation.

8. Plot the radiation level versus distance from the source.

9. Plot the radiation level versus 1/x^2.

Address the following questions in your summary:

1. Which of the two plots is linear? Is it linear over the entire range of measurements?

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. Does 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 III Stefan-Boltzmann Law (high-temperature)

The Stefan-Boltzmann Law states that the intensity of the radiation 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.

1. Before turning on the lamp, measure Tref, the room temperature in degrees Kelvin and Rref, the resistance of the filament of the Stefan-Boltzmann lamp at room temperature.

2. Set up the experiment. The voltmeter should be connected directly to the binding posts of the lamp and an ammeter should be connected in series. The radiation sensor should be at the same height as the lamp filament, 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.

3. Turn on the power supply. Set the voltage 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). Record the voltage across the filament, the current through the filament, and the output from the radiation detector.

4. Calculate the resistance of the filament at each of the voltage settings used.

5. Use the table below to determine the temperature of the filament.

6. Graphically verify the Stephan-Boltzmann Law.

Address these questions in your summary:

1. What is the relationship between the measured radiation and T? Does this hold over the entire range of measurements?

2. The Stefan-Boltzmann Law is perfectly true only for ideal, blackbody radiation. Is the filament a good approximation of a black body?

Table: Temperature and Resistivity for Tungsten

R/R_{300K}	Temp °K
1.0	300
1.43	400
1.87	500
2.34	600
2.85	700
3.36	800
3.88	900
4.41	1000
4.95	1100
5.48	1200
6.03	1300
6.58	1400
7.14	1500
7.71	1600
8.28	1700
8.86	1800
9.44	1900
10.03	2000
10.63	2100
11.24	2200
11.84	2300
12.46	2400
13.08	2500
13.72	2600
14.34	2700
14.99	2800
15.63	2900
16.29	3000
16.95	3100
17.62	3200
18.28	3300
18.97	3400
19.66	3500
26.35	3600