

Lab #6 Stefan-Boltzmann Law

Objective: Examine the relationship between absolute temperature of an object and the relative power radiated per unit area.

Introduction:

The Stefan-Boltzmann Law relates the flux density, or the power per unit area, radiated by an object to T , the absolute temperature of the object. The Law is

$$\frac{1}{A} \frac{dQ}{dt} = I = \frac{P_{rad}}{A} = \epsilon \sigma T^4,$$

where, ϵ is the emissivity and σ is the Stefan-Boltzmann constant which has a value of $5.6703 \times 10^{-8} \text{ W/m}^2 \text{ K}^4$.

In this experiment, you will make relative measurements of the power per unit area emitted from a hot object, namely the Stefan-Boltzmann Lamp filament, at various temperatures. The temperature of the tungsten filament is correlated to its resistivity. You will measure the resistance of the filament and convert that result to a temperature using the known correlation. The relative power per unit area emitted will be measured using a radiation sensor. We will assume that the emissivity for the tungsten filament is one.

Procedure:

You cannot measure the resistance of the filament directly, so you will instead compute the resistance by considering the voltage and current running through the filament. It is important that the voltage into the lab should NEVER exceed 13V. Higher voltages will burn out the filament.

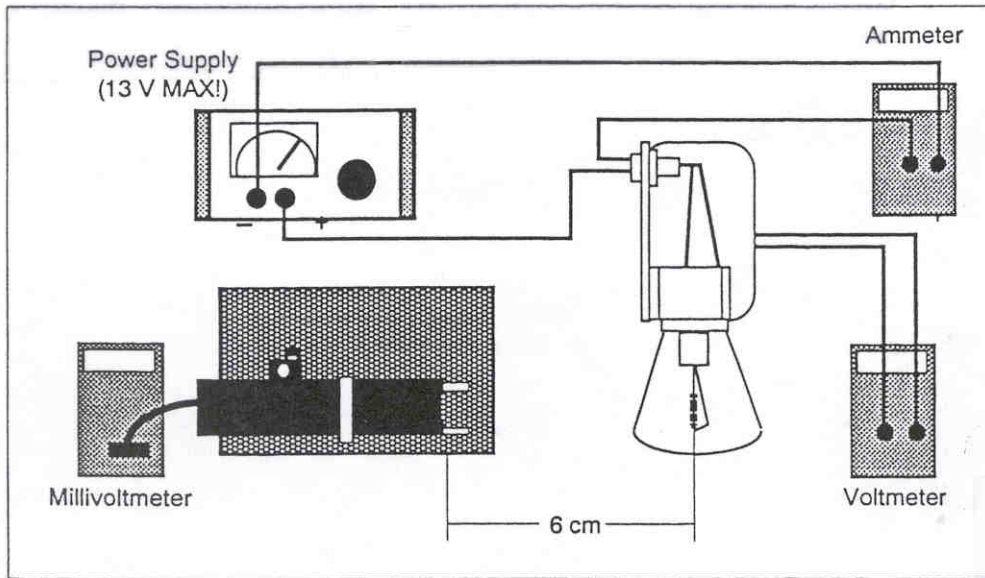
1. Set up the equipment as shown in the figures below. The voltmeter should be connected directly to the binding posts of the Stefan-Boltzmann Lamp. The sensor should be at the same high as the filament, with the front face of the sensor approximately 6cm away from the filament. The entrance angle of the thermopile should include no close objects other than the lamp. Be careful with the alignment as this will improve your results.
2. Before turning on the lamp, measure T_{ref} , the room temperature in Kelvin and R_{ref} , the resistance of the Stefan-Boltzmann Lamp in ohms at room temperature.

$$T_{ref} = \underline{\hspace{4cm}}$$

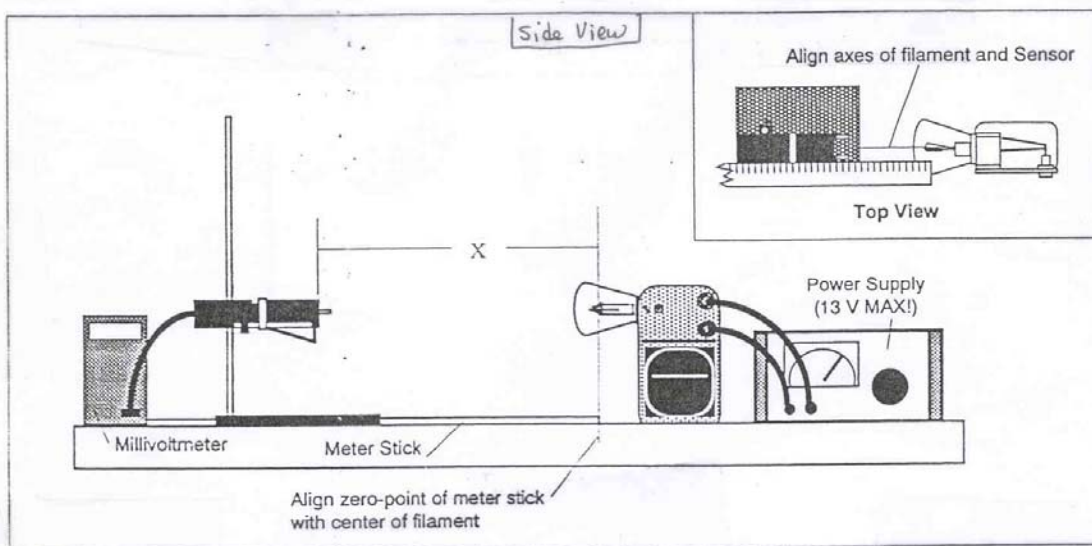
$$R_{ref} = \underline{\hspace{4cm}}$$

3. Turn on the power supply. Set the voltage V to approximately each of the settings listed in the Data Table below. At each voltage setting, record the actual V , I (the current as recorded by the ammeter) and Rad , the reading on the millivoltmeter. Estimate the uncertainties in your measurements (even though you will not propagate these

uncertainties.) **Make each sensor reading quickly. Between readings, place both sheets of insulating foam between the lamp and the sensor, with the silvered surface facing the lamp, so that the temperature of the sensor stays relatively constant.**



Equipment Setup (Overhead View)



Data Table:

Approx Voltage (V)	Actual Voltage (V)	Current (A)	Rad (mV)
1.0			
2.0			
3.0			
4.0			
5.0			
6.0			
7.0			
8.0			
9.0			
10.0			
11.0			
12.0			

Data and Calculations:

1. Enter your voltage and current data into Excel. Compute the resistance of the lamp for each voltage in a new column.
2. The temperature of the filament is correlated with the relative resistivity of tungsten, or the resistance normalized by the resistance at room temperature. You need to transform your measured resistances into relative resistances and then to a temperature. To do this, proceed as follows.
 - a. Divide your calculated resistance by the reference resistance at room temperature.
 - b. Next, you will need to convert these values to temperature. To do this, you will need to make a scatter graph of the data of resistivity versus temperature, which can be found at http://minerva.union.edu/labrades/Temperature_Resistivity_Tungsten.xls. Fit the data with a 3rd order polynomial. This curve fit will give you a formula which when the value of R_{ref} is input, will give a temperature at any resistance. Now, go back to your original spreadsheet and make a new column to hold the computed temperatures. Plug in the formula for the polynomial fit in the form $a_0 + a_1x + a_2x^2 + a_3x^3$, where x is the column address containing the resistance data.
3. Now you have values of the temperature T and the power radiated in your spreadsheet. If you plot these, what type of graph do you get?
4. Transform your data so that the plot becomes linear. What do the slope and y-intercept represent? If the new plot is not linear, is there a range over which it is and could you use this to better fit your analysis?

Write-up:

Write a 1 page summary of your finding and the report will be due on Monday October 23, 2006, in class. Be sure to include answers to the following questions.

- a. What sources of thermal radiation, other than the lamp, might have influenced your measurements? What effect might they have had on your results?
- b. Does the way the lamp is constructed (bulb + filament) affect your measurements in any way?
- c. Are there any systematic effects which might influence the measurement of the thermal radiation by the sensor?
- d. Another source of error is that the Stefan-Boltzmann law is perfectly true only for ideal (blackbody) radiators, or objects that absorb all the radiation which strikes it. Does the lamp filament absorb all of the radiation that strikes it? At high temperature, this effect should be negligible. Why?