3705 Lab: Blackbody radiation from a vacuum filament!

OBJECTIVE: To measure the exponent with which the black body radiation energy flux varies with the temperature.

EQUIPMENT: 20 V power supply, vacuum filament (in a vacuum tube, for example) and two meters (one for volts and one for amps).

THEORY: When we heat up the filament in a vacuum, the only way it can emit energy is in the form of heat condition and radiation. We expect that the power in heat condition will be proportional to the temperature gradient (that is, essentially linear in the temperature) whereas the radiative dispersal of energy away from the filament will follow (approximately) the Stefan-Boltzmann law,

$$P = \sigma T^4 \qquad\qquad \sigma = \frac{\pi^2 k_B^4}{60\hbar^3 c^2} = 5.67\text{x}10^{-8}\ \text{W/m}^2/\text{K}^4$$

By heating a filament in a vacuum with different current loads and measuring its temperature (indirectly, by measuring its resistance!) we will make a plot of the power dissipated as a function of the temperature and determine an estimate of the exponent (in the theory, 4).

One tricky part of this laboratory is the determination of the temperature from the resistance data. The resistance of the filament (tungsten alloy) varies linearly with the temperature. It is designed to be at 1200^oC at the design voltage (about 6.3 V). Using this and the resistance at low temperatures you should be able to determine the temperature of the filament from your resistance data.

PROCEEDURE: Identify the filament of the vacuum tube and hook up the power supply and meters so that you can simultaneously record the voltage across the filament and the current flowing in the filament.

Then slowly at first- record current vs- voltage for voltages up to 12 or more volts. The reason you need to go slowly at first is that the filament takes a while to reach equilibrium at low power levels. When you are at large voltages (anything over 6) you will want to move much more quickly and try to complete the measurements as fast as possible as prolonged operation of the filament beyond its design temperature will eventually destroy it. Turning down the voltage between these measurements may not be a bad idea. To make sure that you havent damaged the filament too much (and theory invalidated the data you collected) as you come down in voltage ascertain whether the resistance returns to the values you had recorded on the way up in voltagesit should!

ANALYSIS: You need to complete two plots and one linefit. One of the plots is the plot of your data, but presented as power ($P = IV$) versus- temperature of the filament

(T). then you need to SUBTRACT from these data the linear part of the heat loss from conduction. You can determine this by fitting the low temperature data with a line then subtracting its extrapolation from the full dataset. Then you need to plot the $log(P)$ (where P is the power with the linear conduction part subtracted) versus $log(T)$ and from that determine the high temperature limit of the slope; that is your estimate of the blackbody energy-vs-temperature exponent.