Blackbody Radiation

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INTRO

This lab focuses on quantifying how thermal radiation affects heat transfer by measuring radiative power and relating it to temperature, distance and aperture size. Additionally, data acquired in the lab is used to experimentally calculate the Stephan-Boltzmann constant and compare it to it's theoretical value.

METHODS

The experimental setup contained a blackbody cavity with a control for setting different temperatures. The cavity contained different circular apertures sizes to radiate the heat from the blackbody to a disc shaped thermopile that collected the reading for the radiative power output. The thermopile was moved to different locations while keeping the aperture size and temperature of the blackbody constant, to obtain a trend between radiative power and distance from the blackbody cavity. Similarly, to obtain a trend between radiative power and aperture size, different apertures were selected while keeping a constant temperature and distance from the blackbody. And to measure the relationship between temperature and radiative power, the temperature of the blackbody cavity was changed while measuring the radiative power from a fixed distance and aperture size.

DISCUSSION

From figures 1 and 2, it can be seen that the plot for temperature vs. radiative power follows a higher order polynomial trend (4^{th} order), while the plot for radiative power vs (Blackbody Temp)^4 – (Ambient Temp)^4 is linear. This follows the theoretical equation for radiation. Changing the aperture size does not lead to a simple linear change in radiative power because it also affects the view factor calculations. This leads to a more complex relationship between aperture size and radiative power but a trend close to linear can be seen in Figure 3, where reducing aperture size reduces the radiative power. Distance is inversely proportional to View factor which in turn is linearly related to radiative power given all else as constant. Therefore the trend of radiative power vs distance from blackbody, shown in Figure 4, is similar to a 1/x graph.

The Experimental value of the Stefan Boltzmann constant is found to be 3.03e-8 W/(m^2 K^4) by performing regression analysis in MATLAB, as can be seen in Figure 5. This shows an error of 4.5% compared to the theoretical value of the constant.. The uncertainty due to temperature measurement contributes the most to the overall uncertainty of the experiment. The measure radiative power does not perfectly agree with the theoretical value as shown in Figure 5, as there is error associated with the calculated Stefan Boltzmann constant. A more precise temperature control could be used to reduce uncertainty.

APPENDIX

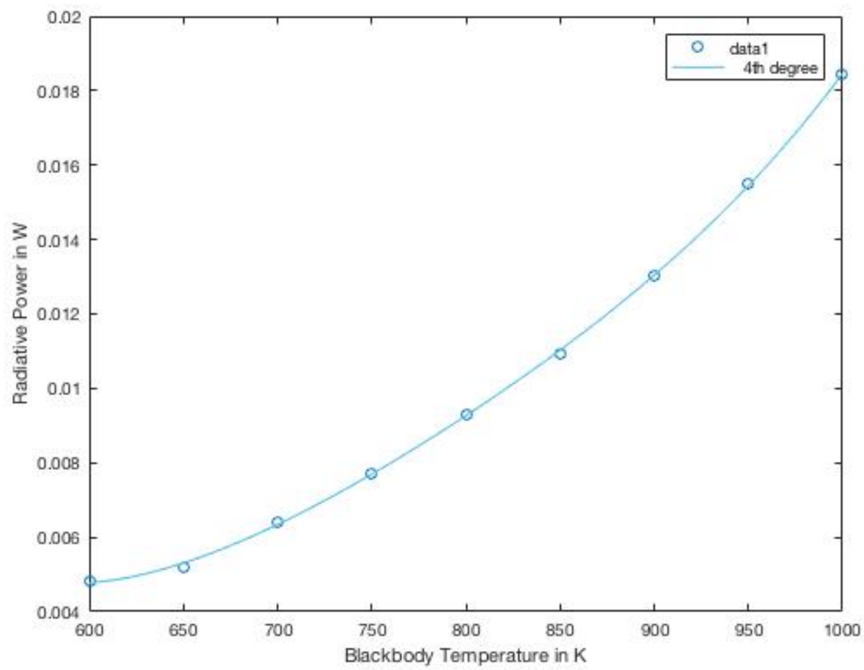

Figure 1: Radiative Power vs Temperature

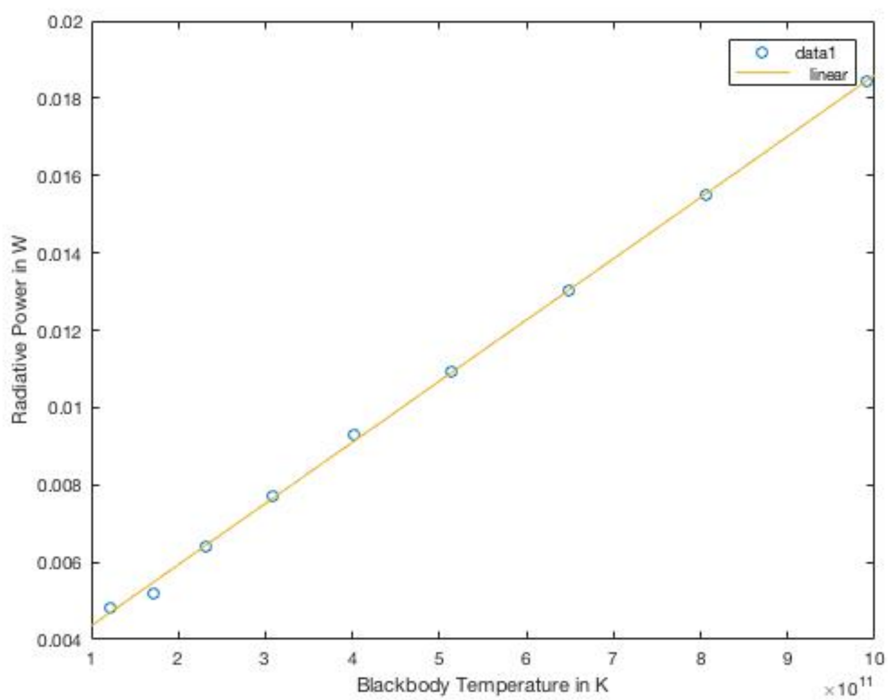

Figure 2: Radiative Power vs. $(\text{Blackbody Temp})^4 - (\text{Ambient Temp})^4$

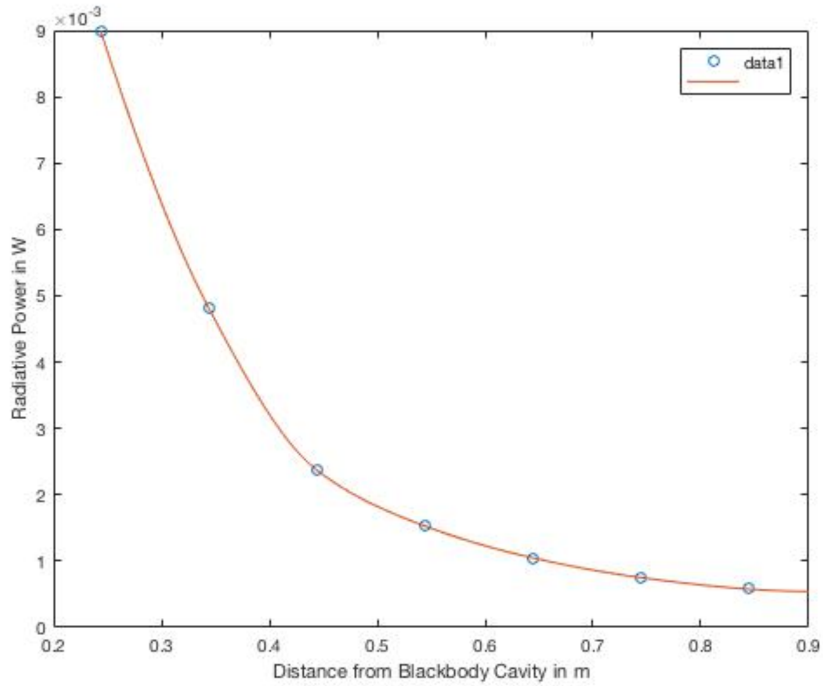

Figure 3: Radiative Power vs Distance from Blackbody

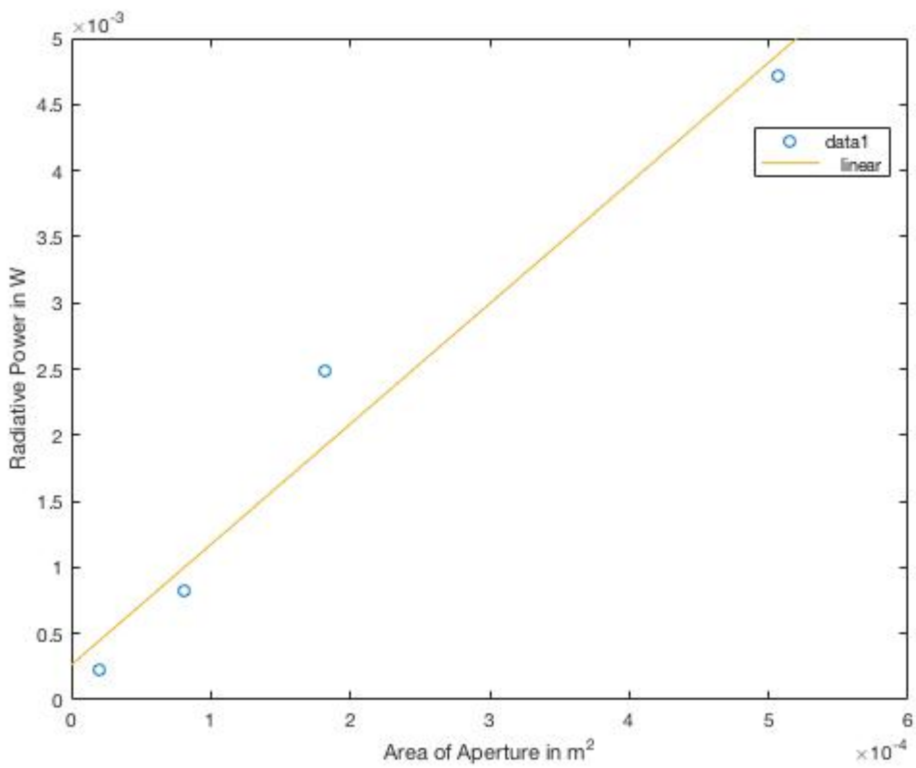

Figure 4: Radiative Power vs Aperture Size

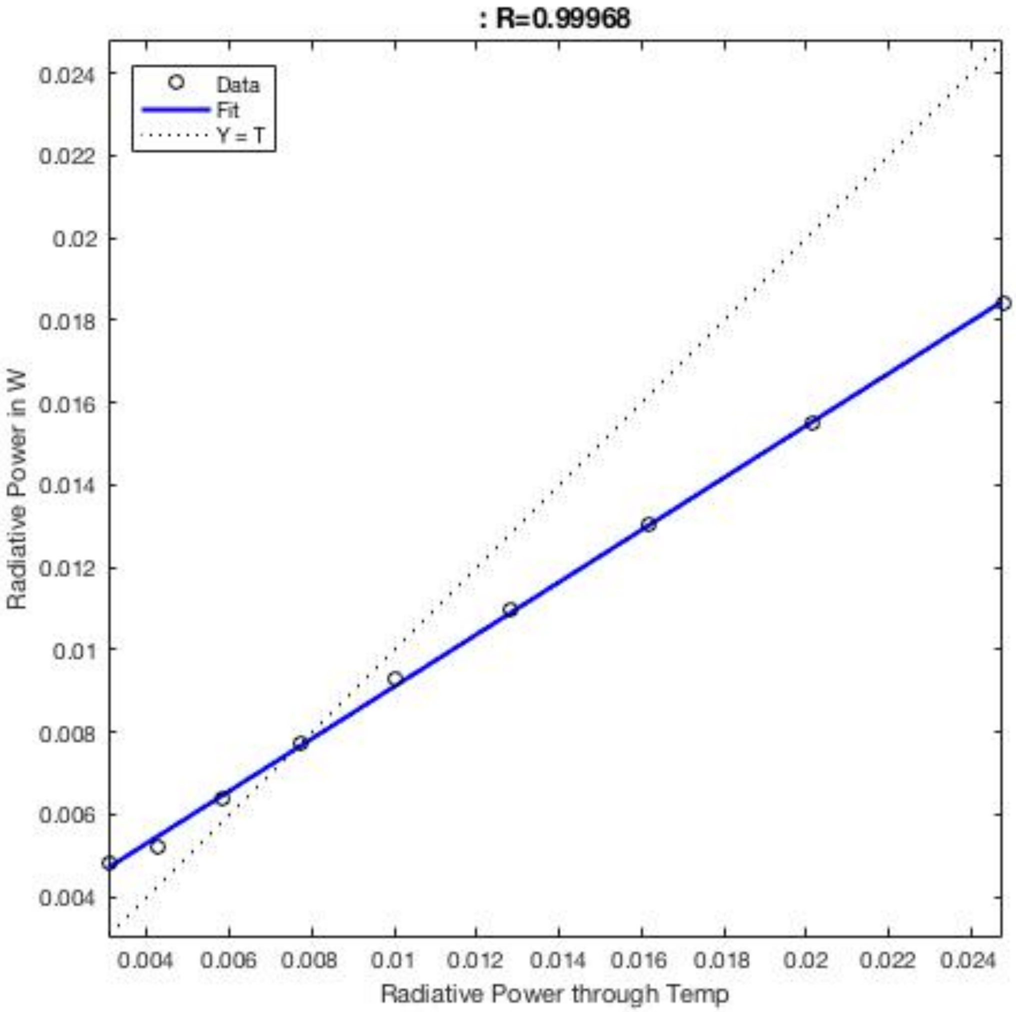

Figure 5: Stefan Boltzmann Constant Regression Analysis