TFES Lab (ME EN 4650)
Blackbody Radiation

Required Figures

Captions

A meaningful and comprehensive caption must accompany all figures and tables. For each of the required plots, the caption is placed *below* the figure and includes the label Figure 1x., where x denotes the letter a–d according to the plot order listed below.

Plots and Tables

1a. On a single figure, plot the measured heat transfer rate, q_{data}, from **all three experiments** versus the corresponding values predicted by theory, q_{theory}, as calculated from equation (14) of the Handout. Plot q_{theory} on the y-axis in units of μW, and q_{data} on the x-axis in units of μW. Use the following marker styles for each experiment: ○ Exp #1 (variable h); □ Exp #2 (variable T); ◇ Exp #3 (variable D). On the same figure, plot the 1:1 line as a solid black line. Include a legend.

Note, a 1:1 line is a line passing through the origin with a slope of 1. If the data agree exactly with the theory, then all data points should fall on the 1:1 line. Deviation of the data from this line indicates limitations in the accuracy and precision of the theory. However, this statement is only true if we are certain that the measurements themselves have negligible error.

1b. Using only the data from **Experiment #1**, plot the measured heat transfer rate, q_{data}, versus the reciprocal of the squared separation distance between the source and detector, $1/h^2$. Plot q_{data} on the y-axis in units of μW, and h^{-2} on the x-axis in units of m^{-2}. Use ○ as the marker style. On the same figure, plot the linear regression line obtained from your analysis as a solid black line. Include a legend with the string "data" for the markers and contains the calculated R^2 value for the fit line in the following string format: "fit, R^2=0.XXXX" where 0.XXXX is your R^2 value to within 4 decimal places.

Note, this type of plot allows one to see relatively quickly whether q is indeed proportional to h^{-2}. Deviation of the data points from the linear regression line reveals instances where the measurements do not agree with the derived theory of blackbody radiation. Note, this does not necessarily mean the theory is incorrect; it simply indicates an inconsistency.

1c. Using only the data from **Experiment #2**, plot the measured heat transfer rate, q_{data}, versus the measured blackbody temperature raised to the fourth power, T^4. Plot q_{data} on the y-axis in units of μW, and T^4 on the x-axis in units of K^4. Use □ as the marker style. On the same figure, plot the linear regression line obtained from your analysis as a solid black line. Include a legend that follows the format of plot 1b.

1d. Using only the data from **Experiment #3**, plot the measured heat transfer rate, q_{data}, versus the squared diameter of the aperture, D^2. Plot q_{data} on the y-axis in units of μW, and D^2 on the x-axis in units of mm^2. Use ◇ as the marker style. On the same figure, plot the linear regression line obtained from your analysis as a solid black line. Include a legend that follows the format of plot 1b.

Short-Answer Questions

2a. Quantify the agreement in q between the measurements and theory based on your results in plot 1a. State your answer in terms of an average percent relative difference, $\bar{\epsilon}$, according to the following relationship

$$\bar{\epsilon} = \frac{1}{N} \sum_{i=1}^{N} \frac{|q_{i_{\text{data}}} - q_{i_{\text{theory}}}|}{q_{i_{\text{theory}}}} \cdot 100\% \,,$$

where N is the total number of data points acquired (over all four experiments). Comment on whether the discrepancy between the measurements and theory seem to be random across the entire q range investigated, or whether there are particular q ranges where the agreement appears better/worse. [2–4 sentences]

2b. Given your results in plots in 1a–1d, including your calculated R^2 values for the curve fits, and using your engineering judgment, assess whether the theory adequately supports the measurements, in terms of the expected dependence of q on T, h, and D. Be specific in your explanation of why or why not. [2–3 sentences]

2c. Assume now that the blackbody cavity in the experiment is replaced with a diffuse "gray body", whose surface temperature can be adjusted uniformly with a heater and thermostat, in a manner similar to what was done in the actual experiment. Describe how you would modify the experimental procedures and/or data analysis in order to determine the unknown emissivity ε of the "gray body". [2–4 sentences]