Heat Transfer Workshop 13 Radiation Introduction

Name ____________________ **Read about gray body Radiation**

The emissivity ε of a surface is a measure of the radiation heat flux or emissive power E that is emitted relative to the maximum from a "black body". This black body emissive power is defined from basic physics as

$$E_b = \sigma T^4$$

where the value of the constant $\sigma = 5.67 \times 10^{-8}$ W/m^2-K^4 when the temperature is specified in Kelvin degrees. The emissivity is then simply

$$\varepsilon = {}^{E}/_{E_b}$$

When there are multiple surfaces exchanging radiation, all of the surfaces are both receiving and emitting energy. If two surfaces are both black ($\varepsilon = 1$) and very near to each other, the view factor between the surfaces is equal to unity and radiation heat flux from surface 1 to surface 2 is simply

$$q"_{12} = E_{b1} - E_{b2} = \sigma\,(T_1^4 - T_2^4)$$

If one of the surfaces is gray ($\varepsilon < 1$), an additional thermal resistance needs to be included as

$$q"_{12} = \frac{E_{b1} - E_{b2}}{1 + \dfrac{1 - \varepsilon_1}{\varepsilon_1}}$$

For this special case show how this reduces to

$$q"_{12} = \varepsilon_1(E_{b1} - E_{b2})$$

Remember this is the radiation flux for two surfaces very close together with one surface black and one gray.

The emissivity is purely a surface property and the radiation can be considered to be purely a surface phenomenon. For example, painting the surface will change the emissivity and the emitted power of a surface regardless of the material of the substrate. This workshop will explore the effects of different surface properties on the radiation exchange at a surface. The measurements will be heat flux $q"_{ps}$ between a heated plate at temperature T_p and a heat sink at temperature T_s.

$$q"_{ps} = \varepsilon_p\left(E_{bp} - E_{bs}\right)$$

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Heat Transfer Workshop 13 Radiation Results

Name ____________________

The challenge of this workshop is to measure the emissivity of a metallic surface. To do this, you are provided with a heated plate that is painted black on one-half of the plate. The other half is polished metal. Note that the plate is at a uniform temperature because it is thick and has high thermal conductivity. It should be heated to about 90°C to easily feel the radiation. Compare the heat transfer from the metal (gray) surface to that of the painted (black) surface ($\varepsilon = 1$) at the same conditions. Use the heat flux sensor to measure the radiation emission from the plate. Mount the sensor onto the small aluminum block from the kit to provide a heat sink. Cover the heat flux sensor with a piece of black (electrical) tape to give a nearly black surface ($\varepsilon = 1$) to the heat flux sensor and to hold it in place.

1. Put your hand close to the plate first over the unpainted half and then the painted half to feel the difference in radiation from the black and gray surfaces. Note how it feels if you move your hand farther away. **DO NOT TOUCH the plate. It is VERY hot.**

2. Without touching the plate, put your free thermocouple between the plate and heater to measure the plate temperature T_p. Hold the mounted heat flux sensor close, but not touching the plate, to measure the net radiation exchange. Take about 20 seconds of data for each of the black and gray surfaces and save in one file. Record the temperatures of the plate and sensor and the measured heat flux from each half of the plate to the sensor below.

	T_p (K)	T_s (K)	q''_{black} (W/m^2)	q''_{gray} (W/m^2)
measured				

3. Describe how the gray surface feels different than the black surface at the same temperature. Why is this?

4. To simplify the system analysis neglect convection and assume that the surfaces are very close (view factor between the sensor and plate is unity). Based on the equations in the introduction show that the ratio of the heat flux for the two cases should be directly proportional to the ratio of the emissivities of the surfaces. Because the sensor is assumed black ($\varepsilon = 1$), show that the gray surface emissivity is equal to the ratio of the gray surface heat flux to the black surface heat flux. Use this equation to find the corresponding emissivity of the polished metal.

Show the equation and then evaluate, ε_{gray} =

5. Explain why the plate did not feel as hot as you moved your hand away from the hot surface. (How does the view factor change?)

6. Based on the measured temperatures, calculate the black body emissive powers of the two surfaces, $E_b = \sigma T^4$. From the equations in the Introduction, calculate the predicted sensor heat flux from the black surface with ε_p=1 to the sensor, q''_{ps}. Explain any differences between the calculated q''_{ps} and measured q''_{black} values of heat flux.

	T_p (K)	T_s (K)	E_{bp} (W/m^2)	E_{bs} (W/m^2)	q''_{ps} (W/m^2)
calculated					

Show equations with calculations: