05/11/2019 - WEEK 5 SUBMISSION

Tuesday, November 5, 2019 10:57 PM

Task 1 : In you own words (which means in your own words) write a summary of the topics about radiative heat transfer we went through including the definitions of emissivity, absorptivity and reflectivity, the view factor, the heat exchange betweeen two black surfaces,the heat exchange between the two gray surface and finally the definition of radiative resistances

Task 2 : Solve the last example you solved in the class (radiative heat exchange between two parallel plates) awhile considering the two emissivities to be 0.1, what can you conclude from the result?

Task 1

RADIATIVE PROPERTIES

Thermal radiation is emitted or absorbed within the first few microns of the surface, and thus we speak of radiative properties of surfaces for opaque materials. Some other materials, such as glass and water, allow visible radiation to penetrate to considerable depths before any significant absorption takes place. Radiation through such semitransparent materials obviously cannot be considered to be a surface phenomenon since the entire volume of the material interacts with radiation.
On the other hand, both glass and water are practically opaque to infrared radiation. Therefore, materials can exhibit different behavior at different wavelengths, and the dependence on wavelength is an important consideration in the study of radiative properties such as emissivity, absorptivity, reflectivity, and transmissivity of materials.

Emissivity

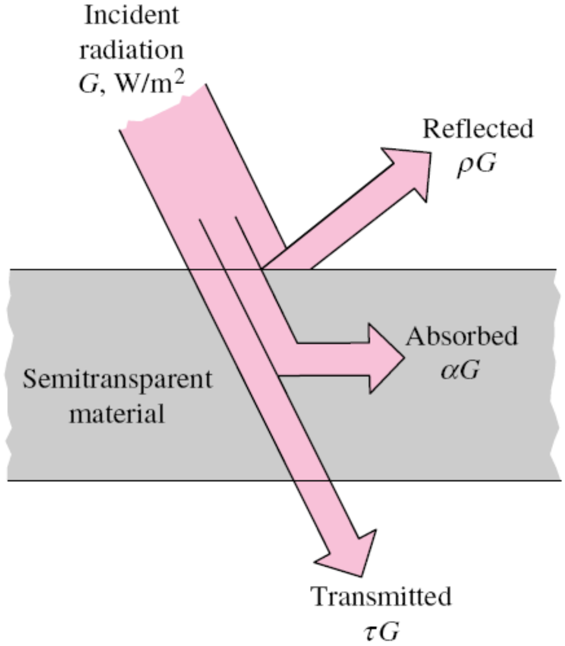
The emissivity of a surface represents the ratio of the radiation emitted by the surface at a given temperature to the radiation emitted by a blackbody at the same temperature. The emissivity of a surface is denoted by ϵ, and it varies between zero and one, $0 \leq \epsilon \leq 1$. Emissivity is a measure of how closely a real surface approximates a blackbody, for which $\epsilon = 1$.

The emissivity of a real surface is not a constant. Rather, it varies with the temperature of the surface as well as the wavelength and the direction of the emitted radiation. The emissivity of a surface at a specified wavelength is called *spectral emissivity* . The emissivity in a specified direction is called *directional emissivity* where is the angle between the direction of radiation and the normal of the surface.

Radiation is a complex phenomenon as it is, and the consideration of the wavelength and direction dependence of properties, assuming sufficient data exist, makes it even more complicated. Therefore, the diffuse and gray approximations are often utilized in radiation calculations. A surface is said to be diffuse if its properties are independent of direction, and gray if its properties are independent of wavelength.

Absorptivity, Reflectivity, and Transmissivity

Everything around us constantly emits radiation, and the emissivity represents the emission characteristics of those bodies. This means that everybody, including our own, is constantly bombarded by radiation coming from all directions over a range of wavelengths. Recall that radiation flux incident on a surface is called irradiation and is denoted by G. When radiation strikes a surface, part of it is absorbed, part of it is reflected, and the remaining part, if any, is transmitted, as illustrated in scheme. The fraction of irradiation absorbed by the surface is called *the absorptivity* α, the fraction reflected by the surface is called *the reflectivity* ρ, and the fraction transmitted is called *the transmissivity* τ.



Absorptivity: $\alpha = \dfrac{\text{Absorbed radiation}}{\text{Incident radiation}} = \dfrac{G_{abs}}{G}, \quad 0 \le \alpha \le 1$

Reflectivity: $\rho = \dfrac{\text{Reflected radiation}}{\text{Incident radiation}} = \dfrac{G_{ref}}{G}, \quad 0 \le \rho \le 1$

Transmissivity: $\tau = \dfrac{\text{Transmitted radiation}}{\text{Incident radiation}} = \dfrac{G_{tr}}{G}, \quad 0 \le \tau \le 1$

$$G_{abs} + G_{ref} + G_{tr} = G$$

RADIATION HEAT TRANSFER

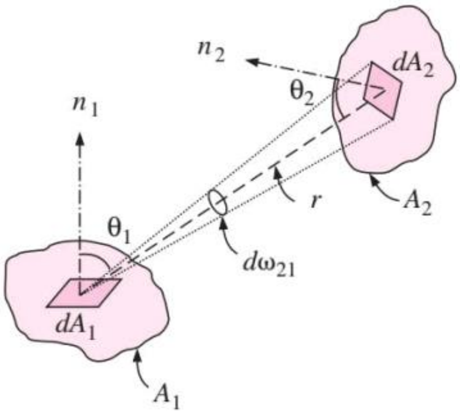
The View Factor

To account for the effects of orientation on radiation heat transfer between two surfaces, we define a new parameter called the view factor, which is a purely geometric quantity and is independent of the surface properties and temperature.

To develop a general expression for the view factor, consider two differential surfaces dA_1 and dA_2 on two arbitrarily oriented surfaces A_1 and A_2, respectively. The distance between dA_1 and dA_2 is r, and the angles between the normals of the surfaces and the line that connects dA_1 and dA_2 are θ_1 and θ_2, respectively. Surface 1 emits and reflects radiation diffusely in all directions with a constant intensity of I_1, and the solid angle subtended by dA_2 when viewed by dA_1 is $d\omega_{21}$.

$$\dot{Q}_{dA_1 \to dA_2} = I_1 \cos\theta_1 dA_1 d\omega_{21} = I_1 \cos\theta_1 dA_1 \frac{dA_2 \cos\theta_2}{r^2}$$

$$\dot{Q}_{dA_1} = J_1 dA_1 = \pi I_1 dA_1$$



RADIATION HEAT TRANSFER: BLACK SURFACES

The blackbody emits and absorbs the maximum amounth of radiation per unit. The radiation is emitted by the blackbody is calculated as

$$\dot{Q}_{emittedByS1AndReceivedinS2} = F_{12} \times E_b = F_{12} \times \sigma T_1^4 \ \left(\frac{W}{m^2}\right)$$

The black surface will emit a certain value of energy E_{b1} from certain area (A) and the other black surface E_{b2} will absorb all the energy coming from the surface 1. So the net formula is radiation leaving the surface 1 and emitting by the surface 2, substracted from the radiation leaving from surface 2 and emitting by the surface 1. And the formula is:

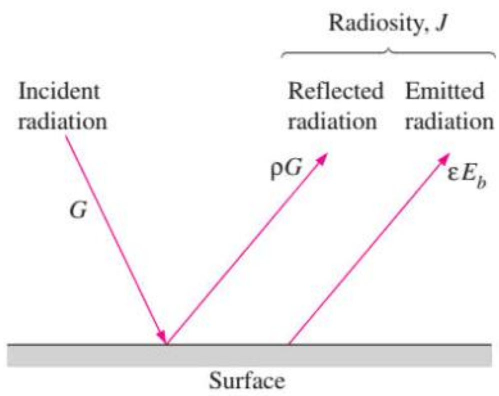
$$\dot{Q}_{netbetween1and2} = \dot{Q}_{emittedByS1AndReceivedinS2} - \dot{Q}_{emittedByS1AndReceivedinS2}$$

$$Q\_1 \to 2 = A_1 \times F_{12} \times \sigma T_1^4 - A_2 \times F_{21} \times \sigma T_2^4$$

$$A_1 \times F_{12} = A_2 \times F_{21}$$

$$Q_{□}1 \rightarrow 2 = A_1 \times F_{12} \times \sigma T_1^4 - A_1 \times F_{12} \times \sigma T_2^4 = A_1 \times F_{12} \times \sigma \left(T_1^4 - T_2^4\right)$$

RADIATION HEAT TRANSFER: GREY SURFACES



In reality, most of the surfaces have grey bodies. The grey bodies absorb a certain amount of radiation while reflecting some of the radiation back from the surface into space. G irradiation is the total radiation that comes in contact with a surface per unit time and unit area. While J represents the radiosity which is the total amount of radiation that is reflected off a surface per unit time and unit area. Can be calculated with this formula:

$$J_i = \epsilon \times E_b + (1 - \epsilon_i)G \rightarrow G = \frac{J_i - \epsilon_i \times E_b}{(1-\epsilon_i)} \rightarrow$$

$$\dot{Q_i} = A_i\left(J_i - \frac{J_i - \epsilon_i \times E_b}{(1-\epsilon_i)}\right) = \frac{A_i\,(J_i - \epsilon_i J_i - J_i + \epsilon_i \times E_b)}{1-\epsilon_i} = \frac{A_i \times (\epsilon_i \times E_b - \epsilon_i J_i)}{1-\epsilon_i} = \frac{A_i \epsilon_i}{1-\epsilon_i} \times \left(E_b - J_i\right)$$

Task 2 : Solve the last example you solved in the class (radiative heat exchange between two parallel plates) awhile considering the two emissivities to be 0.1, what can you conclude from the result?

$\epsilon_1 = \epsilon_2 =$ 0.1, A1 = 1.5 m^2, F_{12} = 0.01 , T_1 = 298 K, T_2 = 308 K

$$\dot{Q}_{net_{2-1}} = \frac{A\sigma(T_2^4 - T_1^4)}{\frac{1}{\epsilon_2} + \frac{1}{\epsilon_1} - 1}$$

$= 1.5 \text{ x } (5.67\text{x}10^{-8}) \text{ x } (308^4 - 298^4)/\ 1/0.1 - 1/0.1 - 1$

$= 4.9822$ W