Week 5_Qureshi, Nahid

Question 1
In your 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 between two black surfaces,the heat exchange between the two gray surface and finally the definition of radiative resistances.

Answer

Radiant Intensity
Radiant intensity can be defined as the amount of radiation emitted by a source in a particular direction per unit solid angle.

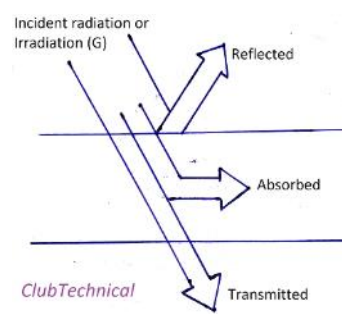
Emissivity
The emissivity of the surface of a material is its effectiveness in emitting energy as thermal radiation. Quantitatively, emissivity is the ratio of the thermal radiation from a surface to the radiation from an ideal black surface at the same temperature as given by the Stefan–Boltzmann law. The ratio varies from 0 to 1. The emissivity of a real surface varies with the temperature of the surface as well as the wavelength and the direction of the emitted radiation.

Irradiation (G)
Irradiation of a surface is defined as the total radiant energy received per unit area from all direction at all wavelength.

Radiosity (J)
Every surface emits radiation as well as reflects it. Radiation leaving a surface consists of emitted and reflected compound.
Radiosity is defined as amount of radiation energy emitted from a surface per unit surface area. The total radiation emitted by surface is sum of energy emitted by surface plus reflected irradiation transmitted.

Absorptivity
The fraction of irradiation absorbed by the surface is called the absorptivity (α). It is the ratio of absorbed radiation (G abs) to incident radiation (G). Its value: $0 \leq \alpha \leq 1$

Reflectivity
The fraction of radiation reflected by the surface is called the reflectivity (ρ). It is the ratio of reflected radiation (G ref) to incident radiation (G). Its value: $0 \leq \rho \leq 1$



Transmissivity
The fraction of radiation transmitted is called the transmissivity (τ). It is the ratio of transmitted radiation (G tr) to incident radiation (G). Its value: $0 \leq \tau \leq 1$

$\alpha+\rho+\tau=1$
For opaque surfaces, $\tau=0$, and thus
$\alpha+\rho=1$

This is an important property relation since it enables us to determine both the absorptivity and reflectivity of an opaque surface by measuring either of these properties.

View Factor

View factor is the fraction of radiant energy emitted per unit area by one body and directly intercepted by another. It is also called shape factor or configuration factor.

It is generally denoted by F12 i.e. shape factor of body-1 with respect to body-2. It is a fraction and hence a dimensionless quantity.
If A1 is the total area of radiating surface of body-1 having shape factor F12 w.r.t. receiver body-2 then the total radiant energy leaving surface-1 and directly intercepted by surface-2 is =A1F12

View factor of a radiant body depends on the
1. geometrical dimensions i.e. surface area
2. configuration of radiating surface with respect to receiver &
3. inter-spatial distance of radiant body with respect to receiver.

View factor $\propto \frac{1}{\text{Surface area of emitterShape factor}\propto 1\text{Surface area of emitter}}$

View factor $\propto$ Surface area of receiver

View factor $\propto \frac{1}{\text{Inter-spatial distance}}$

Heat exchange between two black surfaces

A black surface will emit a radiation of E_{b1} per unit area per unit time. If the surface is having A_1, unit area, then it will emit $E_{b1} * A_1$ Radiation in unit time. This radiation will go to the other black surface and totally absorb by it but at the same time. The 2nd black body will emit its radiation $E_{b2} * A_2$ per second and it will go to Ist body and totally absorbed by it .The whole process happened simultaneously .So the net heat transfer between these surfaces will be the net heat per second (power) gained by any of the two surfaces (obviously same for both surfaces). The net heat transfer 1s the radiation leaving the entire surface | that strikes surface 2 subtracts the radiation leaving the entire surface 2 that strikes surface 1, which is, in formula:

$$E_{b1} * A_1 * F_{1-2} - E_{b2} * A_2 * F_{2-1}$$

Heat exchange between two grey surfaces

A gray surface will reflect/absorb a given fraction of the thermal radiation a blackbody surface would absorb. More importantly, the gray body/blackbody fraction is independent of radiation wavelength.

For a given grey body surface i, with the area A_i , emitting a radiation of E_{bi} per unit area per unit time. The net heat transfer is the radiation leaving the entire surface i subtracts the radiation incident on the entire surface i, which is, in formula: $A_i(J_i - G_i)$. The radiosity J can be calculated by the formula: $\mathcal{E}_i E_{bi} + (1 - \mathcal{E}_i)G_i$

Radiative Resistance

Radiative Resistance is the value to measure the energy depleted by loss resistance which is converted to heat radiation, the energy lost by radiation resistance is converted to radio waves.

Question

Find the net radiative heat exchange between the surface 1 and surface 2 where $A_1 = 1.5\ m^2, \mathcal{E}_1 = 0.1, \mathcal{E}_2 = 0.1, T_1 = 298K, T_2 = 308K,\ \sigma = 5.67 * 10^{-8} \frac{W}{m^2K^4}$.

Answer

According to the formula,

$$\dot{Q}_{net2-1} = \frac{A\sigma(T_2^4 - T_1^4)}{\frac{1}{\mathcal{E}_1} + \frac{1}{\mathcal{E}_2} - 1}$$

$$\dot{Q}_{net2-1} = \frac{1.5m^2 * 5.67 * 10^{-8} \frac{W}{m^2K^4} * (308^4 - 298^4)K^4}{\frac{1}{0.1} + \frac{1}{0.1} - 1}$$

= 4.9823 W

Meanwhile under situation, based on the following formula

$$F_{2-1} = \frac{1}{\frac{1}{\mathcal{E}_1} + \frac{1}{\mathcal{E}_2} - 1} = \frac{1}{\frac{1}{.1} + \frac{1}{.1} - 1} = 0.0526$$

When $F_{1-2} = 0.01$,

$$\dot{Q}_{net1-2} = AF_{1-2}(T_2^4 - T_1^4)$$

$= 1.5m^2 * 0.01 * 5.67 * 10^{-8} \frac{W}{m^2K^4} * (298^4 - 308^4)K^4$

= -0.9466 W

$\therefore A_1 = A_2$

$\dot{Q}_{net2-1} = -\dot{Q}_{net1-2} = 0.9466\ W$

Comparing the two values of net heat exchange, we can see the value of emissivity will significantly affect the radiative heat exchange between two grey surfaces.