Submission 5 - Technical Environmental Systems

1. **In you own words, write a summary of the topics about radiative heat transfer, 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.**

Radiative heat transfer refers to the transfer of heat between objects in the form of electromagnetic waves. All objects above absolute zero temperature emit thermal radiation. Thermal radiation is observed in the wavelength range from 100 µm to 0.1µm (Infrared, Visible light and higher wavelength Ultraviolet rays). Radiative heat transfer depends on the temperature of the surface; the intensity of radiation emitted depends on the wavelength and direction of the waves.
A black body is an ideal body which is a perfect absorber and emitter of thermal radiation. The thermal energy emitted by a black body, $E_B = \sigma T^4$

Emissivity (ϵ): Emissivity is defined as the thermal radiation emitted by a surface at a given temperature with respect to the radiation emitted by a black body at the same temperature. Thus, the emissivity of a black body will be 1.
$\epsilon = \frac{E}{E_B}$, $0 \le \epsilon \le 1$

Absorptivity (α): Absorptivity is defined as the thermal radiation absorbed by a surface with respect to the irradiation G received (G refers to the total radiation flux incident on the surface).
$\alpha = \frac{G_{abs}}{G}$, $0 \le \alpha \le 1$

-According to Kirchoff's Law, the total hemispherical emissivity of a surface at temperature T is equal to its total absorptivity of radiation emitted by a black body at the same T, i.e., $\epsilon = \alpha$

Reflectivity (ρ): Reflectivity is defined as the thermal radiation reflected by a surface with respect to the irradiation G received (G refers to the total radiation flux incident on the surface).
$\rho = \frac{G_{ref}}{G}$, $0 \le \rho \le 1$

For an opaque surface (Transmissivity=0), $\alpha + \rho = 1$

View Factor ($F_{1\to2}$):
View factor is a geometric quantity which describes the fraction of radiation leaving surface 1 that is intercepted by surface 2. This quantity is independent of the surface properties.

According to reciprocity law: $A_1 . F_{1\to2} = A_2 . F_{2\to1}$

Heat exchange between two black surfaces ($\dot{Q}_{1\to2}$):
In the case of two black bodies, the radiation leaving the surface is only emitted, not reflected. Therefore, the heat exchange arises from the emission of radiation of the two surfaces.

$$\dot{Q}_{1\to2} = \textit{Radiation leaving surface } 1 \;\&\; \textit{striking surface } 2 - \textit{Radiation leaving surface } 2 \;\&\; \textit{striking surface } 1$$

$$= A_1 E_{B1} F_{1\to 2} - A_2 E_{B2} F_{2\to 1}$$

According to reciprocity law, $A_1 . F_{1\to 2} = A_2 . F_{2\to 1}$

$$Thus, \dot{Q}_{1\to 2} = A_1 F_{1\to 2}\, \sigma(T_1^4 - T_2^4)$$

Heat exchange between two gray surfaces ($\dot{Q}_{1\to 2}$):

For gray surfaces, radiation leaving the surfaces is both, reflected as well as emitted. This total radiation leaving the gray surface is defined as radiosity (J):

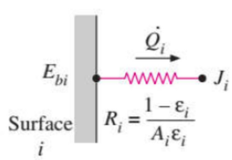
$$\dot{Q}_{1\to 2}$$
$$= Radiation\ leaving\ surface\ 1\ \&\ striking\ surface\ 2$$
$$- Radiation\ leaving\ surface\ 2\ \&\ striking\ surface\ 1$$
$$= A_1 J_1 F_{1\to 2} - A_2 J_2 F_{2\to 1}$$

According to reciprocity law, $A_1 . F_{1\to 2} = A_2 . F_{2\to 1}$

$$Thus, \dot{Q}_{1\to 2} = A_1 F_{1\to 2}\,(J_1 - J_2) = \frac{(J_1 - J_2)}{R}$$

$$R = \frac{1}{A_1 F_{1\to 2}}$$

Radiative Resistances (R):

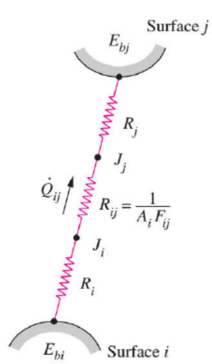


Radiative heat transfer between a surface and the surroundings,

$$\dot{Q}_i = AJ_i - AG_i = \frac{A_i\epsilon_i}{1-\epsilon_i}(E_{Bi} - J_i)$$

Radiative resistance of the surface, i, is therefore defined as:

$$R_i = \frac{1-\epsilon_i}{A_i\epsilon_i}$$

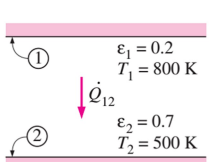


In the case of net heat transfer between two surfaces:

$$\dot{Q}_{i\to j} = A_i F_{i\to j}(J_i - J_j)$$

$$R_{i\to j} = \frac{1}{A_i F_{i\to j}}$$

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



$$\dot{\boldsymbol{Q}}_{\mathbf{1\to2}} = \boldsymbol{\sigma}(T_1^4 - T_2^4)/(\frac{\mathbf{1}}{\boldsymbol{\epsilon}_\mathbf{1}} + \frac{\mathbf{1}}{\boldsymbol{\epsilon}_\mathbf{2}} - \mathbf{1})$$

$$= 5.67 * 10^{-8} * (800^4 - 500^4)/(\frac{1}{0.1} + \frac{1}{0.1} + 1) = \mathbf{937.17\ W/m2}$$

Previously, for emissivity values 0.2 and 0.7, $\dot{Q}_{1\to2}$ was 3625.369 W/m2.

Thus, it can be concluded that, lower the emissivity of the two parallel plates, lower is the net radiative heat exchange between them.