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Task 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 grey surface and finally the definition of radiative resistances.

Radiative Heat transfer:

Radiation happens in an object that has a temperature higher than zero. Which is 0K or -273̊ C. Heat transfer from the body with a high temperature to a body with low temperature by radiation is called heat radiation. Thermal radiation does not require a medium, so the bodies do not need to have physical contact. Since absolute zero is an idealised physical condition, thermal radiation happens almost in all objects, regardless of the state of matter it is, i.e. solid, liquid or gasses. In short we can say that, everything around us emits radiation to its surrounding. Rate of emission increases with the temperature.

Definition of Emissivity:

The emissivity (Ɛ) of the material refers to the effectiveness of the surface in emitting energy as Thermal Radiation. Mathematically it is defined as the ratio of the thermal radiation emitted by the surface at a temperature to the radiation emitted by a blackbody at the same temperature. 0 ≤ Ɛ ≤ 1. The value varies from 0 to 1. Greater the value of emissivity, less distance from the surface of blackbody (Ɛ=1).The emissivity of a real surface varies with temperature of the surface as well as the wavelength and the direction of the emitted radiation.

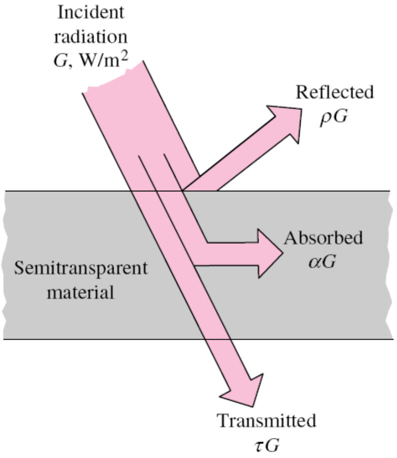
Definition of Absorptivity:

Absorptivity (α) of the surface of a material is measured by the capability of a material to absorb radiation. i.e. Effectiveness in absorbing radiant energy. The ratio of the radiation absorbed by the incident radiant power to calculate the value of absorptivity. Value varying from 0 to 1.

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

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

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



Definition of Radiosity:
The calculation of radiation heat transfer between surfaces involves the total radiation energy streaming away from a surface, with no regard for its origin. That is why we need to define the quantity that represents the rate radiation energy leaves a unit area of a surface in all directions.

Definition of reflectivity:
Reflectance (ρ) of the surface of a material is its effectiveness in the reflecting radiant energy. It is the fraction of total energy transmitted by the body, we use the ratio of the reflected radiation on the incident radiant power to calculate the value of absorptivity, the value varying from 0 to1.

Definition of View factor:
View factor (F) is the fraction of radiation leaving one surface which is intercepted by a second surface. The intensity of the emitted radiation depends on the view factor of the surface relative to the sky.
It is the degree to which heat carried by radiation can be passed between two surface.

Blackbody and Graybody:
Blackbody is an object which absorbs all the radiant energy reaching its surface from all directions. It is a perfect absorbing body while Graybody is a body whose absorptivity of surface does not vary with variation in temperature and wavelength of the incident radiation. It is a non-ideal emitter. It will partially absorb, reflect and emit energy it receives.

Heat exchange between two black surfaces:
A black surface will emit radiation of E_{b1} per unit area per unit time. If the surface is having A1 unit area, then it will emit $E_{b1} * A_1$ Radiation in unit time. This radiation will reach other black surface and totally absorb it but at the same time, second black body will emit its radiation $E_{b2} * A_2$ Radiation in unit time. It will not go to first blackbody and get completely absorbed. The entire process occur simulatneously. So the net heat transfer between these surfaces will be the net heat per second (power) gained by any of the two surfaces i.e. equal for both surfaces. The net heat transfer is the radiation leaving the entire surface 1 and strikes surface 2, subtracts the radiation leaving the entire surface 2 that strikes surface 1, which is in formula
$A_1 E_{b1} F_{1\rightarrow 2} - A_2 E_{b2} F_{2\rightarrow 1}$

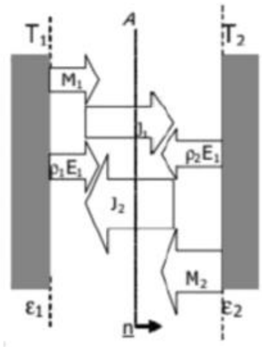
Heat exchange between two grey surfaces:
A grey surface will reflect/ absorb a given fraction of the thermal radiation by a blackbody surface would absorb. More importantly, the graybody/blackbody fraction is independent of radiation wavelength.
For a given graybody surface i, with the area A_1, emitting radiation E_{hi} per unit area per unit time.

Radiative Resistance:
Radiative resistance is a value to Measure the energy depleted by loss resistance which is converted to heat radiation. The energy lost by radiation is converted to radio waves. It can be calculated by this formula

R1 = $\frac{1-\varepsilon_1}{A_i \varepsilon_i}$

Task 2

Find the net radiative heat exchange between the surface 1 and 2 where A_1 = 1.5 m^2, ε_1 =0.1, ε_2 = 0.1, T_1 =298 K , T_2 =308K, σ= 5.67* 10^{-8} W/ m^2 K^4



As per formula,

$$\dot{Q}_{12,\text{ no shield}} = \frac{A\sigma(T_1^4 - T_2^4)}{\frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2} - 1}$$

$$\dot{Q}_{net_{2-1}} = \frac{1.5\, m^2 * (5.67 * 10^{-8}) * (308^4 - 298^4) K^4}{\frac{1}{0.1} + \frac{1}{0.1} - 1} = 4.9823W$$

$$F_{2-1} = \frac{1}{\frac{1}{\varepsilon_2} + \frac{1}{\varepsilon_1} - 1} = \frac{1}{\frac{1}{0.1} + \frac{1}{0.1} - 1} = 0.0526W$$

When F $_{1-2}$ = 0.01

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

$$\dot{Q}_{net_{2-1}} = 1.5 * 0.01\ * (5.67 * 10^{-8}) * (298^4 - 308^4) \quad = \ -0.9466W$$

But $A_1 = A_2$

$$F_{2-1} = \frac{A_1 \sigma\ (T_1^4\ - T_2^4)}{\frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2} - 1} = -\frac{A_1 \sigma\ (T_1^4\ - T_2^4)}{\frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2} - 1}$$

$$\dot{Q}_{net_{2-1}} = -\dot{Q}_{net_{1.2}} = 0.9466W$$

By comparing the two values of net heat exchange under different situation, we can see that the value of emissivity would greatly affect the radiative heat exchange the surfaces.