WEEK 5

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

Radiative Heat Transfer

Heat propagation for radiation occurs because every body whose temperature is higher than the absolute zero emits electromagnetic radiations. The radiation propagates in form of oscillations through electromagnetic waves. These latter are defined through wavelength λ (distance run by the wave for a complete oscillation), frequency f (number of complete oscillations run in time unity),and propagation velocity c (velocity of propagation of electromagnetic waves). Wavelength, frequency and velocity are linked together through the formula: $c= \lambda \cdot f$

Absorptivity and Reflectivity

The radiation flux (Φi) hitting a surface (a material) is partly transmitted, partly reflected, partly absorbed.

Absorptivity (a) is the ability of the material(surface)to absorb thermal radiation.

ABSORPTANCE

$$\alpha = \frac{\Phi_a}{\Phi_i}$$

Reflectivity (ρ) is the ability of the material to reflect the thermal radiation.

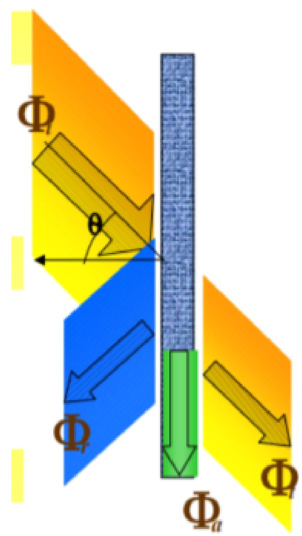
REFLECTANCE

$$\rho = \frac{\Phi_r}{\Phi_i}$$

In addition , *Transmittivity (τ)* is the ability of the material to transmit the thermal radiation.

TRANSMITTANCE

$$\tau = \frac{\Phi_t}{\Phi_i}$$



$$\boxed{\alpha + \rho + \tau = 1}$$

$$\alpha, \rho, \tau = f(\lambda, \theta)$$

Emissivity

Real bodies, such as the building materials, can be fruitfully modeled as “gray bodies” that is bodies which emit and absorb (independently of wavelength and direction) a constant fraction of the radiant energy the black body emits and absorbs at the same temperature. This fraction is called emissivity (ε): its value ranges from 0 (ideal reflector) and 1 (black body).

For gray bodies, black body’s law still apply, by introducing in Planck’s and Stefan Boltzmann’s laws ε is considered as a correction reduction factor.

According to Kirchhoff's law, the emissivity is equal to the absorptance (absorbed energy to incident energy ratio): ε = a .

$$\epsilon = \frac{E_{theRealOne}}{E_{blaclBody@thatTemperature}} = \frac{E_{theRealOne}}{\sigma T^4} \rightarrow$$

$$E_{theRealOne} = \epsilon \times \sigma T^4$$

View Factor

The view factor is the geometrical quantity corresponding to the fraction of the radiation leaving the surface I that strikes the other surface j. It does not depend on the surface properties. It is known for the shape factor ,configuration factor and angle factor.

$$\mathrm{F}_{12} = \frac{\dot{q}_{\downarrow} emittedBySurface1AndReceivedinSurface2}{\dot{q}_{emittedBySurface1}}$$

Heat exchange between two black surfaces

The black body is an ideal model radiator used to study the electromagnetic radiation emission:

- For each temperature, for each wavelength and for each direction, the black body absorbs all the radiant energy hitting it and emits the maximum amount of energy

-The black body emits uniformly in all directions

-The black body's global and spectral emission power is according to Planck's, Stefan-Boltzmann's and Wien's laws.

$$\dot{Q_{12}} = \dot{Q}_{emittedBySurface1AndReceivedinSurface2} - \dot{Q}\_emittedBySurface2AndReceivedinSurface14$$

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

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

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

Heat exchange between two gray surfaces

The heat exchanged between 2 gray bodies is expressed through the equation:

$$\begin{aligned}\dot{\mathbf{Q}} &= \mathbf{F}_{\varepsilon} \cdot \mathbf{F}_{1,2} \cdot \mathbf{A}_1 \cdot \boldsymbol{\sigma} \cdot \left(\mathbf{T}_1^4 - \mathbf{T}_2^4\right) \quad \mathbf{[W]} \\ &= \mathbf{F}_{\varepsilon} \cdot \mathbf{F}_{2,1} \cdot \mathbf{A}_2 \cdot \boldsymbol{\sigma} \cdot \left(\mathbf{T}_1^4 - \mathbf{T}_2^4\right)\end{aligned}$$

F1,2 e F2,1 are view factors Fε is a function of the 2 emissivity values of the 2 bodies, as well as of their geometry.

For building application purposes, above equation can be simplified (linearization o f the equation):

$$\dot{\mathbf{Q}} = \mathbf{A} \cdot \mathbf{h}_r \cdot \left(\mathbf{t}_1 - \mathbf{t}_2\right) \quad \mathbf{[W]}$$

The coefficient of radiant heat exchange (hr), expressed in [W/m2K], and depends on:

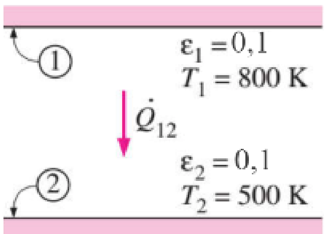
- Emissivity of the 2 gray bodies;
- Relative position of the 2 bodies (view factor)
- Absolute temperatures of the 2 gray bodies.

Radiative Resistance

The radiative resistance is the value to measure the energy defeated by loss resistance which is converted to heat radiation and the energy lost by radiation resistance is converted to electromagnetic waves.

TASK 2

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



$$\dot{Q}_{1\,2} = \frac{A \cdot \sigma \, (T_1^4 - T_2^4\,)}{\dfrac{1}{\varepsilon_1} + \dfrac{1}{\varepsilon_2} - 1}$$

$$\dot{Q}_{1\,2} = \frac{1 \cdot 5{,}67 \cdot 10^{-8} \, (800^4 K - 500^4 K\,)}{\dfrac{1}{0{,}1} + \dfrac{1}{0{,}1} - 1} = 1035{,}81 \, W$$

Due to this result, I can conclude that the lower the emissivity the lower the heat transfer.