Task 1

Emissivity

Emissivity is defined as the ratio of the energy radiated from a material's surface to that radiated from a perfect emitter, known as a blackbody, at the same temperature and wavelength and under the same viewing conditions. It is a dimensionless number between 0 (for a perfect reflector) and 1 (for a perfect emitter). $0 \le \varepsilon \le 1$

Real surface:
$\varepsilon_\theta \neq$ constant
$\varepsilon_\lambda \neq$ constant

Diffuse surface:
$\varepsilon_\theta =$ constant

Gray surface:
$\varepsilon_\lambda =$ constant

Diffuse, gray surface:
$\varepsilon = \varepsilon_\lambda = \varepsilon_\theta =$ constant

The emissivity of a surface depends not only on the material but also on the nature of the surface.

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, Transmissivity

Irradiation

The 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 above Figure.

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: $0 \le \alpha \le 1$

Reflectivity

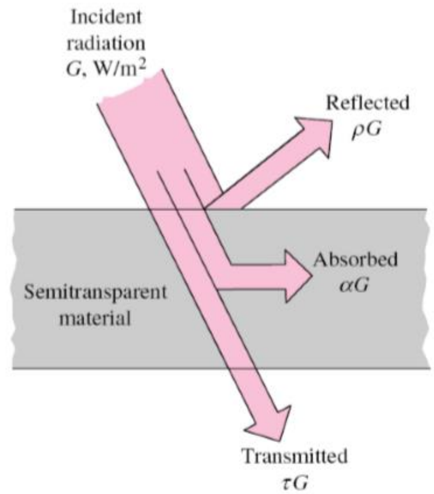
The fraction of radiation reflected by the surface is called the reflectivity (ρ). It is the ratio of reflected radiation (G_{ref}) to incident radiation (G).

Its value: $0 \le \rho \le 1$

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: $0 \le \tau \le 1$



The first law of thermodynamics requires that the sum of the absorbed, reflected, and transmitted radiation energy be equal to the incident radiation. That is,

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

Dividing each term of this relation by G yields

$\alpha+\rho+\tau=1$

For opaque surfaces, $\tau=0$, and thus

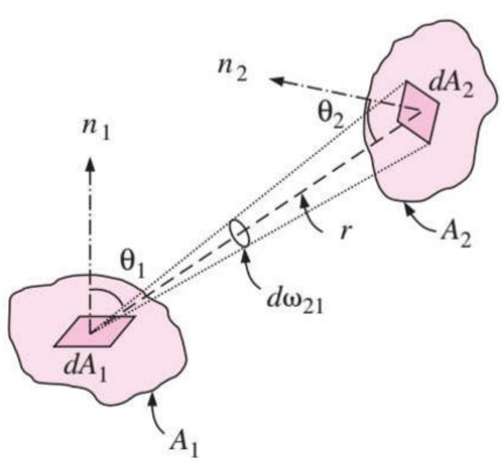
$\alpha+\rho=1$

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

A view factor, $F_{A\rightarrow B}$, is the proportion of the radiation which leaves surface A that strikes surface B. In a complex scene there can be any number of different objects, which can be divided in turn into even more surfaces and surface segments.

The fraction of thermal energy leaving the surface of object 1 and reaching the surface of object 2, determined entirely from geometrical considerations. Stated in other words, F_{12} is the fraction of object 2 visible from the surface of object 1, and ranges from zero to 1. This quantity is also known as the Radiation Shape Factor. Its units are dimensionless.



The heat exchange between two black Surfaces

Consider two black surfaces of arbitrary shape maintained at uniform temperatures *T*1 and *T*2. Recognizing that radiation leaves a black surface at a rate of *Eb* = s*T* 4 per unit surface area and that the view factor *F*1 ® 2 represents the fraction of radiation leaving surface 1 that strikes surface 2, the *net* rate of radiation heat transfer from surface 1 to surface 2 can be expressed as

$$\dot{Q}_{1\rightarrow 2} = \begin{pmatrix}\text{Radiation leaving}\\ \text{the entire surface 1}\\ \text{that strikes surface 2}\end{pmatrix} - \begin{pmatrix}\text{Radiation leaving}\\ \text{the entire surface 2}\\ \text{that strikes surface 1}\end{pmatrix}$$

$$= A_1 E_{b1} F_{1\rightarrow 2} - A_2 E_{b2} F_{2\rightarrow 1} \qquad \text{(W)}$$

❖Applying the reciprocity relation: $A_1F_{1\rightarrow 2} = A_2F_{2\rightarrow 1}$

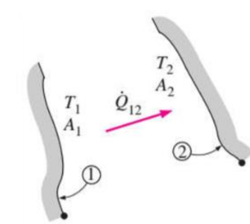
$$\dot{Q}_{1\rightarrow 2} = A_1 F_{1\rightarrow 2}\,\sigma(T_1^4 - T_2^4)$$

This is the desired relation. A negative value for Q1 ® 2 indicates that net radiation heat transfer is from surface 2 to surface 1. Now consider an enclosure consisting of N black surfaces maintained at specified temperatures. The net radiation heat transfer from any surface i of this enclosure is determined by adding up the net radiation heat transfers from surface i to each of the surfaces of the enclosure:

❖For an enclosure with multiple surfaces:

$$\dot{Q}_i = \sum_{j=1}^{N} \dot{Q}_{i\rightarrow j} = \sum_{j=1}^{N} A_i F_{i\rightarrow j}\sigma(T_i^4 - T_j^4)$$

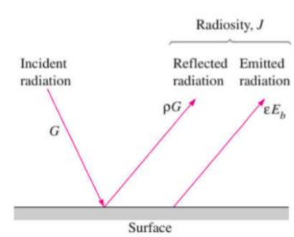
Again a negative value for *Q* indicates that net radiation heat transfer is *to* surface *i* (i.e., surface *i gains* radiation energy instead of losing). Also, the net heat transfer from a surface to itself is zero, regardless of the shape of the surface.



The heat exchange between two grey surfaces and Radiation resistances

Radiosity J: the total radiation energy leaving a surface per unit time and per unit area.

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.



The net rate of radiation heat transfer from a surface i

$$\dot{Q}_i = \begin{pmatrix}\text{Radiation leaving} \\ \text{entire surface } i\end{pmatrix} - \begin{pmatrix}\text{Radiation incident} \\ \text{on entire surface } i\end{pmatrix}$$
$$= A_i(J_i - G_i) \qquad \text{(W)}$$

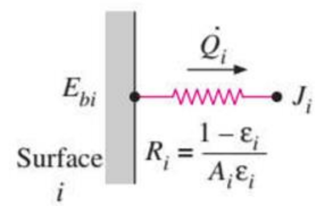
$$\dot{Q}_i = A_i\left(J_i - \frac{J_i - \varepsilon_i E_{bi}}{1 - \varepsilon_i}\right) = \frac{A_i \varepsilon_i}{1 - \varepsilon_i}(E_{bi} - J_i)$$

Surface resistance to radiation

$$\dot{Q}_i = \frac{E_{bi} - J_i}{R_i} \qquad R_i = \frac{1 - \varepsilon_i}{A_i \varepsilon_i}$$

The surface resistance to radiation for a blackbody is zero since ε = 1 and J = Ebi

Reradiating surface: Some surfaces are modeled as being adiabatic since their back sides are well insulated and the net heat transfer through them is zero.



Task 2

A=1.5 $\varepsilon_{1,2}$=0.1 $\sigma = 5.67 * 10^{-8}$ T_1=298 T_2=308

$Q_{1,2}$= $\frac{A*\sigma(\mathrm{T}_1^4 - \mathrm{T}_2^4)}{\frac{1}{\varepsilon_1}+\frac{1}{\varepsilon_2}-1}$ $F_{1,2}$= $\frac{1}{\frac{1}{\varepsilon_1}+\frac{1}{\varepsilon_2}-1}$

$Q_{1,2}$= $\frac{1.5*5.67*10^{-8}(298^4-308^4)}{\frac{1}{0.1}+\frac{1}{0.1}-1}$ =-0.466 w

$F_{1,2}$= $\frac{1}{\frac{1}{0.1}+\frac{1}{0.1}-1}$ =0.0526

$Q_{1,2=}\ A * F_{1,2} * \sigma(\mathrm{T}_1^4 - \mathrm{T}_2^4)$

$Q_{1,2=}\ 1.5 * 0.0526 * 5.67 * 10^{-8} * (298^4 - 308^4)$=-4.97

The heat transfer between two surfaces is affected by emissivity of each surface.