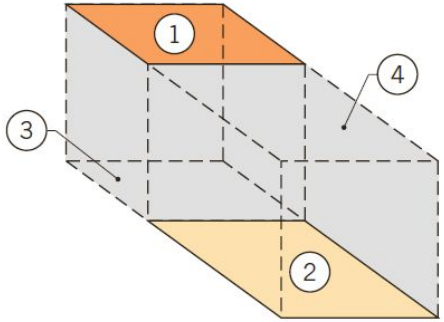
13.42 Consider two very large parallel plates with diffuse, gray surfaces.

Determine the irradiation and radiosity for the upper plate. What is the radiosity for the lower plate? What is the net radiation exchange between the plates per unit area of the plates?

Determine the view factor F12



A cavity composed of three, infinitely long and opaque surfaces have the following conditions at the steady state:

Surface 1: T1 = 300 °C, L1 = 0.5 m, ε1 = 0.7.
Surface 2: T2 = 200 °C, L2 = 0.5 m, ε2 = 1.
Surface 3: T3 = 100 °C, L3 = 0.5 m, ε3 = 1.

Determine the net heat rate for each surface and verify that the sum of the heat rates is equal to 0.

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Radiosity Surface 1

$J_1 = \sigma T_1^4 = 5.67e4\ W/m^2$

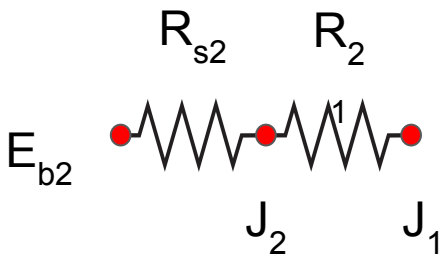
Radiosity Surface 2

$J_2 = \varepsilon_2 \sigma T_2^4 + (1-\varepsilon_2) J_1 = 1.418e4\ W/m^2$

Irradiation Surface 1

$G_1 = F_{12} J_2 + F_{13} J_3 + \ldots =$

$= J_2 = 1.418e4\ W/m^2$



Basic Energy Balance on surface 1

$q_1 = \sigma T_1^4 - G_1 = 4.25e4\ W/m^2$

Basic Energy Balance on surface 2

$q_2 = \varepsilon_2 (\sigma T_2^4 - J_1) = \varepsilon_2 \sigma (T_2^4 - T_1^4) =$

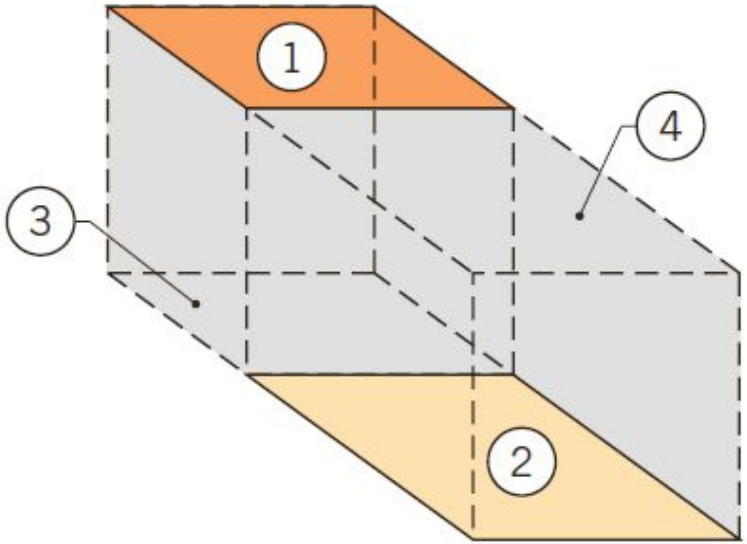
$= -4.25e4\ W/m^2$

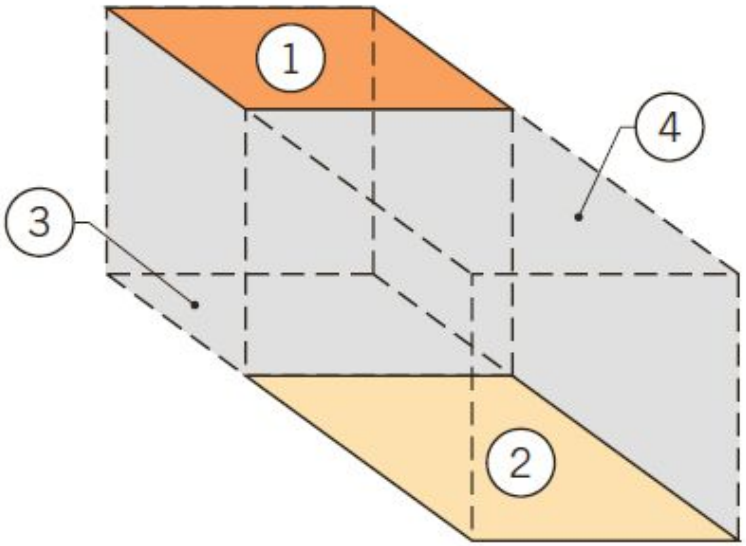
Energy Balance based on the surface resistance of surface 2

$q_2 = (\sigma T_2^4 - J_2)/R_{s2} = -4.25e4\ W/m^2$

$R_{s2} = (1-\varepsilon_2)/\varepsilon_2 = 0.25$

Determine the view factor F12 as a function of known or calculable view factors.





$$Q_{(1+4)-(2+3)} = Q_{(1+4)-2} + Q_{(1+4)-3} =$$

$$= Q_{1-2} + Q_{4-2} + Q_{1-3} + Q_{4-3}$$

$$A_{(1+4)}F_{(1+4)-(2+3)} = A_1F_{1-2} + A_4F_{4-2} +$$

$$+ \quad A_1F_{1-3} + A_4F_{4-3}$$

$$A_4F_{4-3} = A_2F_{2-1} = A_1F_{1-2}$$

$$F_{1-2} = (A_{(1+4)}F_{(1+4)-(2+3)} - A_4F_{4-2} - A_1F_{1-3})/2A_1$$

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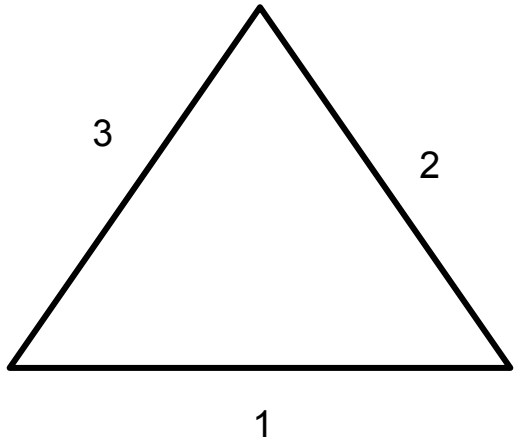

View Factors

$F_{12}+F_{13} = 1,\ F_{12} = F_{13} = 0.5$

Energy Balance on surface 1

$q_1 = L_1\varepsilon_1\sigma(F_{12}(T_1^4 - T_2^4) + F_{13}(T_1^4 - T_3^4)) =$

$= 1.452e3\ W/m$

Irradiation Surface 1

$G_1 = F_{12}J_2 + F_{13}J_3 = 1.97e3\ W/m^2$

Radiosity Surface 1

$J_1 = \varepsilon_1\sigma T_1^4 + (1-\varepsilon_2)G_1 = 4.874e3\ W/m^2$

Energy Balance on surface 2

$q_2 = L_2(F_{21}(E_{b2} - J_1) + F_{32}(E_{b2} - E_{b3})) =$

$= -72.53\ W/m$

Energy Balance on surface 3

$q_3 = L_3(F_{31}(E_{b3} - J_1) + F_{32}(E_{b3} - E_{b2})) =$

$= -1.379e3\ W/m$

Validation

$q_1 + q_2 + q_3 = 0$

Energy Balance based on the surface resistance of surface 1

$Rs1 = (1-\varepsilon_1)/(L_1\varepsilon_1) = 0.8571\ 1/m$ $\qquad$ $q_1 = (\sigma T_1^4 - J_1)/R_{s1} = 1.452e3\ W/m$