1. You have just bought a new radiometer and you are interested in examining the radiative properties of some different metal plates you found in a box.

a. Explain shortly the concept of *Radiosity* and write an expression that shows how the radiosity for a surface is dependent on the radiative properties and the temperature of the surface. (1p)

The plates in the box consists of different metals, but you can't tell them apart by looking at them. Instead, you figured that you could calculate the emissivity of a plate using your radiometer and compare your value to what is found in tables. The box is said to contain plates of *aluminum*, *chrome-nickel*, and *oxidated steel* with tabulated emissivity's as *0.10*, *0.65* and *0.95* respectively.

b. A plate that you selected at random, is shaped as a square with one side being 0.1m. Your radiometer detector is circular with a radius of 5 mm. You have placed the metal plate and the radiometer detector with a distance so that the view factor from the plate (1) to the detector (2) is 0.007. What are the view factors F_{21} & F_{23}? Where "3" corresponds to the very large surroundings? (1p)

c. Using your radiometer, you are measuring a total radiative heat flux into your detector of 880 W/m^2 as you are directing it towards the plate. Removing the plate, the total radiative heat flux from the surrounding to the detector is measured to 400 W/m^2. As you are examining the plate it holds a temperature of 110°C. Which of the three metals are you examining? You may neglect any radiative heat transfer contribution from the detector to the metal surface in your calculations. (4p)

2. Explain how a vacuum at the absorbing surface in a thermal solar collector may reduce the collector's heat losses. (1p)

3. Arranging the mirrors in a concentrated solar power park, using a solar power tower, requires a certain land area. What problems are related to using a too small land area, that is arranging the mirrors too close to each other? How does this affect the efficiency of the CSP plant? (2p)

SOLUTIONS

1. a. The radiosity is all radiation leaving a surface, that is radiation emitted from the surface itself, and reflected incident radiation (irradians). The surface temperature affects the emitted radiation from the surface:

$$J = E + \rho G = \varepsilon \sigma T^4 + \rho G$$

b. We can calculate the area of the metal plate and the radiometer detector:

$$A_1 = 0.1 * 0.1 = 0.01\ m^2$$

$$A_2 = r_2^2 \pi = 0.005^2 * \pi = 7.854 * 10^{-5}$$

The surrounding is specified as very large. Assuimg that the detector doesn't see anything else then the plate and the surrounding. Using the view factor $F_{12} = 0.007$, the reciprocity relation and the summation rule:

$$F_{21} = \frac{F_{12} A_1}{A_2} = \frac{0.007 * 10^{-2}}{7.854 * 10^{-5}} = 0.891$$

$$F_{23} = 1 - F_{21} = 0.109$$

c. We want to find the emissivity of the plats, ε_1, using the expression found in a.:

$$J_1 = \varepsilon_1 \sigma T_1^4 + \rho_1 G_1$$

We assume a grey and opaque body:

$$\rho_1 = 1 - \alpha_1 - \tau_1 = 1 - \varepsilon_1$$

$$J_1 = \varepsilon_1 \sigma T_1^4 + (1 - \varepsilon_1) G_1$$

$$\varepsilon_1 = \frac{J_1 - G_1}{\sigma T_1^4 - G_1}$$

We could neglect any contribution from the small radiometer detector. The irradiation to the plate is the measured heat flux from the surrounding, which is measured when we don't have the plate, that is the radiosity from the surrounding:

$$G_1 = J_3 = 400\ W/m^2$$

We need to find the radiosity from the plate: J_1

Looking towards the plate, the total heat flux to the detector is measured:

$$G_2 = 880\ W/m^2$$

Which is the sum of the contributions from the plate and the surroundings:

$$A_2 G_2 = A_1 F_{12} J_1 + A_3 F_{32} J_3 = A_2 F_{21} J_1 + A_2 F_{23} J_3$$

$$G_2 = F_{21} J_1 + F_{23} J_3$$

$$J_1 = \frac{G_2 - F_{23} J_3}{F_{21}} = \frac{880 - 0.109 * 400}{0.891} = 938.72\ W/m^2$$

We can now calculate the emissivity:

$$\varepsilon_1 = \frac{938.72 - 400}{5.67 * 10^{-8} * (110 + 273)^4 - 400} = 0.656$$

This value is close to what is tabulated for chrome-nickel. Since the emissivities tabulated for the aluminum and oxidized steel are far from this value, the plate we have examined is most probably chrome-nickel.

2. Creating a vacuum at the absorbing surface removes the convective heat loss that would otherwise occur. The heat loss is now only due to radiation.

3. Arranging the mirrors too close to each other may cause *shadowing* and *blocking* of solar radiation. Shadowing is caused when one mirror hinders solar radiation to reach another mirror since it is in the path of the incoming solar radiation. Blocking is caused when a mirror hinders the reflected solar radiation from one mirror to reach the absorbing surface at the solar tower.
Both shadowing and blocking will reduce the efficiency of the CSP plant since less radiation reaches the absorbing surface.