View Factors

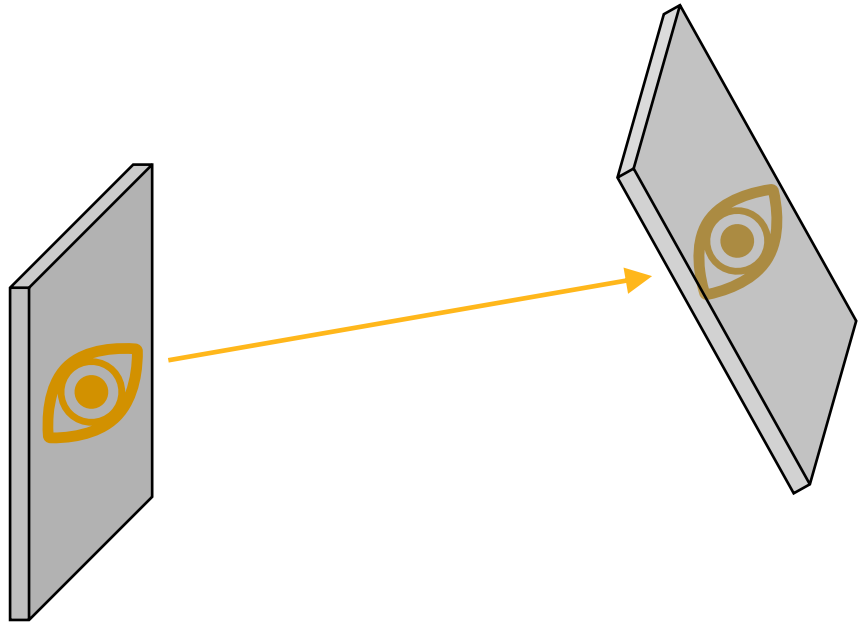
Thermal Radiation in Heat Transfer
Analysis – Lesson 2

What is the View Factor?

The **View Factor** is the portion of the radiative heat flux which leaves surface A that strikes surface B.

- In simpler terms, the view factor measures how well one surface can see another surface.
- View factors are purely **geometrical parameters** and are independent of the physical surface properties and temperature.

$$Q_{ij} = A_i \varepsilon_i F_{ij} \sigma (T_i^4 - T_j^4)$$



Why is the View Factor Important for Radiation?

Radiation heat transfer between surfaces depends on the **orientation** of the surfaces.

- On a hot summer day, when a person turns their face directly to the sun, the hot sensation felt on the face is much stronger compared to when they turn their back to the sun.

Why is the View Factor Important for Radiation?

Why is the view factor important?

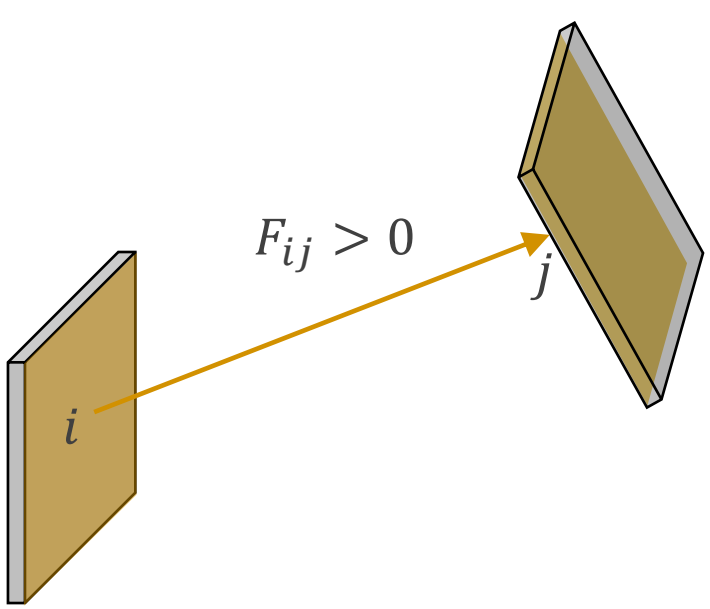
- In a room with a fireplace, the radiation from the fireplace to the walls differs for each wall, depending on their distance and angle to the fire. Thermal radiation to the different surfaces of the furniture varies, too.

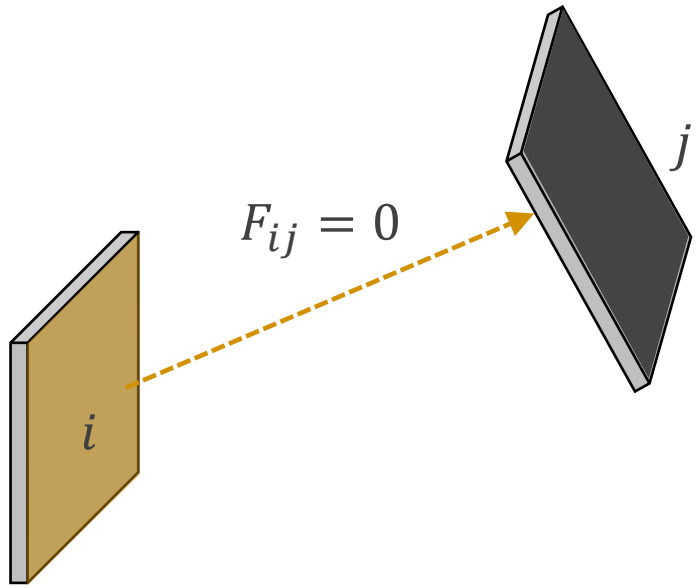
About View Factors

The view factor F_{ij} is a scalar value varying between 0 and 1.

- In general, $0 \leq F_{ij} \leq 1$
- When surfaces see each other, F_{ij} does not equal 0.
- When surfaces cannot see each other, F_{ij} equals 0.

$$Q_{ij} = A_i \varepsilon_i F_{ij} \sigma (T_i^4 - T_j^4)$$

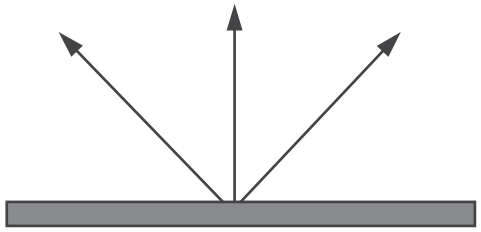




About View Factors (cont.)

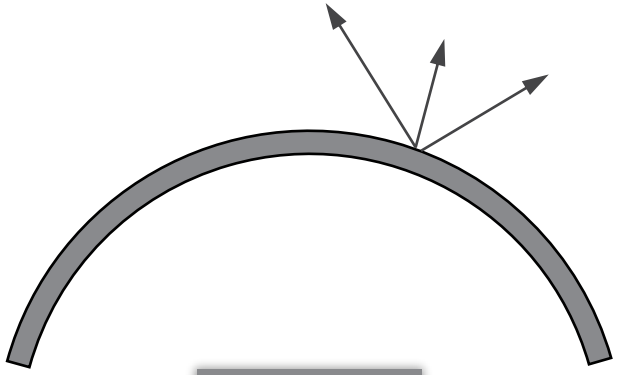
For self-viewing surfaces:

- For a plane or convex surface, the view factor is 0.
- For a concave surface, the view factor is between 0 and 1; it cannot have a value of 0.



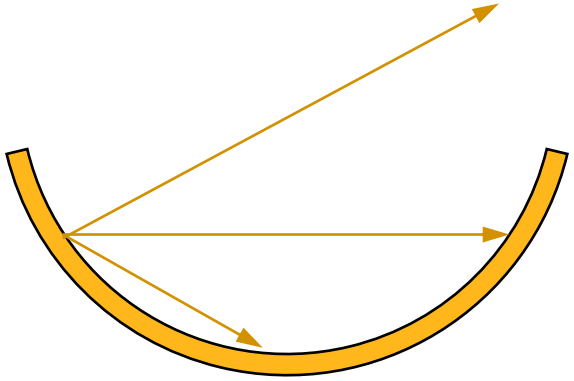
Plane

$F_{ii} = 0$



Convex

$F_{ii} = 0$



Concave

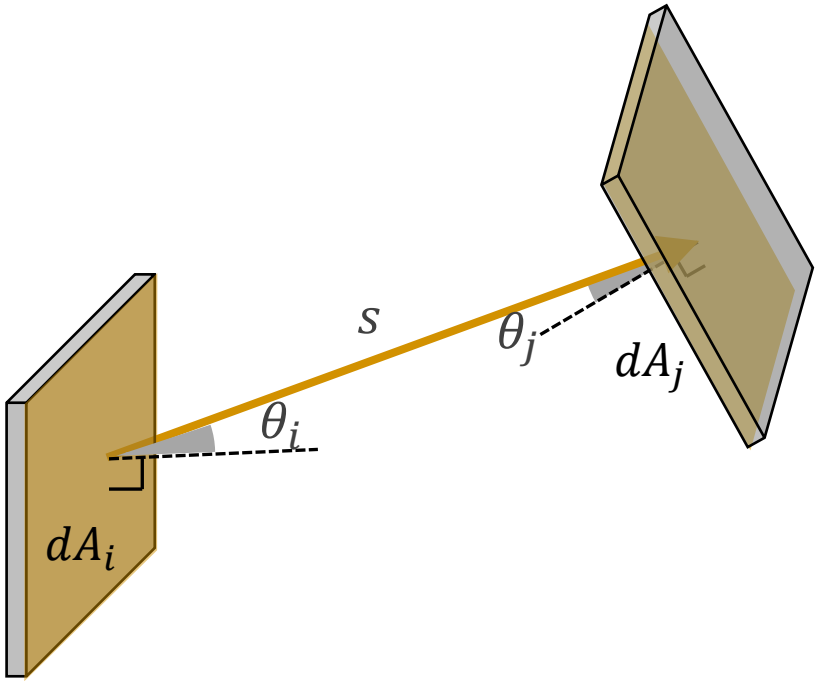
$1 > F_{ii} > 0$

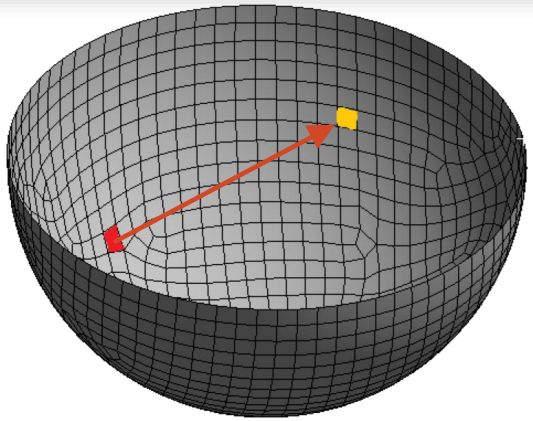
Calculating the View Factor

The view factor is calculated based on the area, distance and angles between the surface normals.

- For two **infinitesimal surfaces i and j** with differential areas dA_i and dA_j, the view factor from surface i to surface j can be calculated by:

$$dF_{ij} = \frac{cos\theta_i cos\theta_j}{\pi s^2} dA_j$$





The finite element solver finds dF for all meshed surfaces participating in radiation.

Reciprocity Rule

What's the relationship between F_{ij} and F_{ji}?

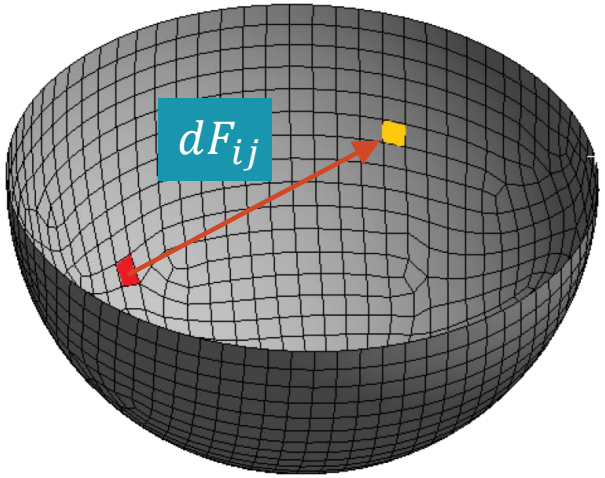
$$dF_{ij} = \frac{cos\theta_i cos\theta_j}{\pi s^2} dA_j$$

- Intergrating dF_{ij} over surface i leads to:

$$F_{ij} = \frac{1}{A_i} \int_{A_i} \int_{A_j} \frac{cos\theta_i cos\theta_j}{\pi s^2} dA_j dA_i$$

- **Reciprocity rule**

$$F_{ij} A_i = F_{ji} A_j$$



In general, F_{ij} is not equal to F_{ji}. Only when $A_i = A_j$, $F_{ij} = F_{ji}$.

Summation Rule

Radiation may occur within **a perfect or closed enclosure**. Conservation of energy requires that the radiation leaving any surface of a closed enclosure be received by the other surfaces of the enclosure. This means that no radiative heat escapes from a perfect enclosure.

- The sum of the view factors from surface i of an enclosure to all surfaces of the enclosure, including to itself, must equal unity.

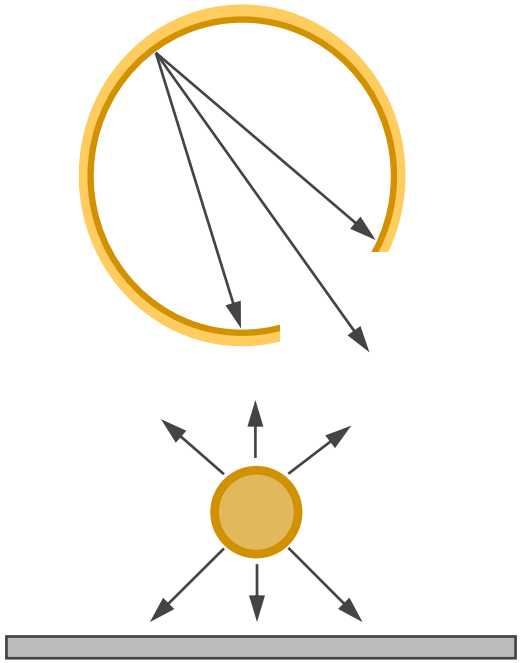
$$\sum_{j=1}^{n} F_{ij} = 1$$

In a closed room, the view factor from the fireplace surface to all the objects in the room adds up to 1.

Open Enclosures

Radiation occurs for both perfect and open enclosures.

- In an open enclosure, heat can be lost to the environment/space. The summation of the view factors may not equal 1.



- Radiation from a campfire to the people surrounding it

View Factors for Simple Geometries

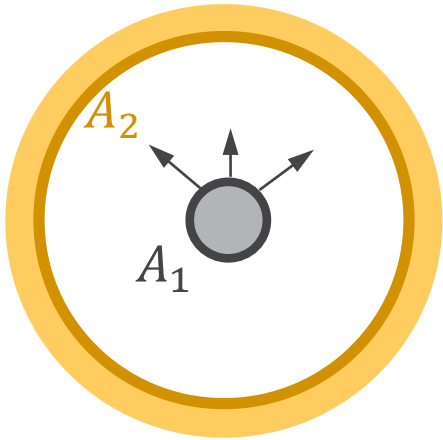
Find the view factor by inspection for a simple geometry.

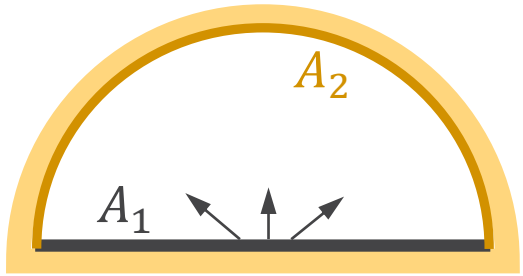
- Surface 1 is convex: $F_{11} = 0$
- Surface 1 can **only** see surface 2, $F_{12} = 1$
- Find F_{21} by Reciprocity Rule:

Reciprocity $\quad F_{21} = \frac{A_1}{A_2} F_{12}$

- Find F_{22} by Summation Rule:

Summation rule $\quad F_{21} + F_{22} = 1$





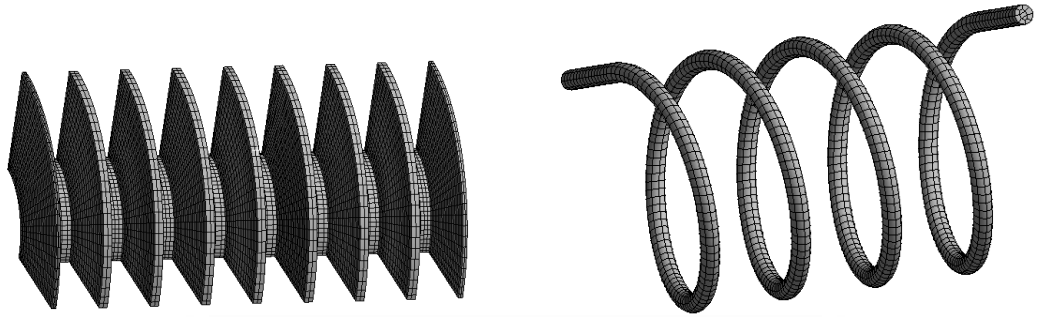
Summary

In general, calculating view factors is not an easy task, except for the simplest geometries. We rely on numerical methods to find view factors for arbitrary geometries.

- Using the finite element method, an arbitrary geometry is discretized to a number of elements. For each element face involved in radiation, view factors are calculated.
- If there are 1,000 element surfaces involved in radiation, the view factor matrix will be 1,000 x 1,000.

View factor matrix

$$\boldsymbol{F} = \begin{bmatrix} \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots \end{bmatrix}$$



$$dF_{ij} = \frac{cos\theta_i cos\theta_j}{\pi s^2} dA_j dA_i$$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