Heat Transfer: Radiation

View factor calculation rules

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HEATQUIZ

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Learning goals

Summation Rule:

- Sum of view factors for one object is 1!

$$\sum_j \phi_{ij} = 1$$

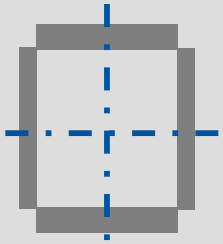
Reciprocal Rule:

- Determine view factors from looking at the opposite surface or object

$$\phi_{ij} \rightarrow$$
$$\leftarrow \phi_{ji}$$

Other Rules for View Factors:

- Smart usage of symmetry conditions
- Identify meaningful auxiliary planes

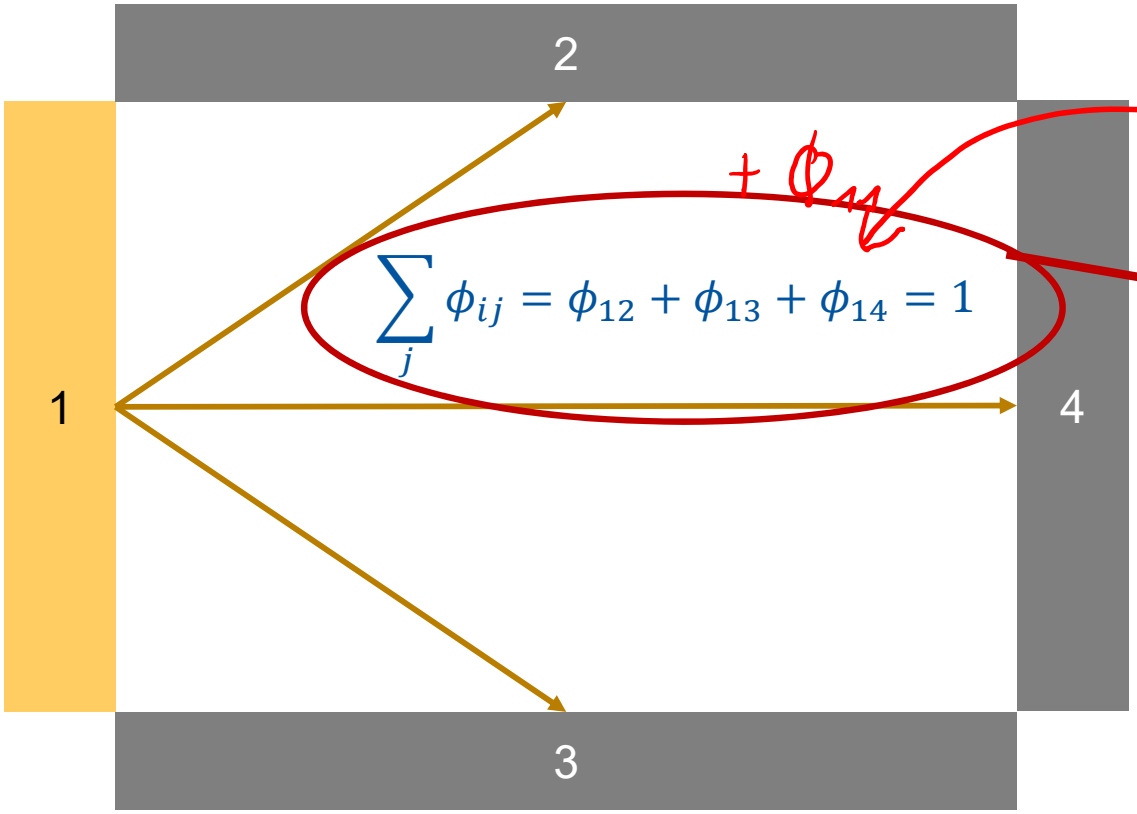


View Factors Cooking Recipe

Summation Rule:

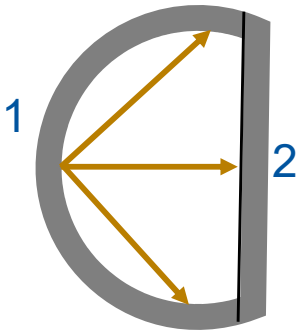
$\sum_j \phi_{ij} = 1$

- The radiation which goes out from a surface i, "does not get lost" and therefore must itself be completely distributed onto the surrounding surfaces j = 1,2,3,…



For concave surfaces, the Body irradiates also to itself

1. Index = sender
2. Index = receiver



$\phi_{12} + \phi_{11} = 1$

is often forgotten!

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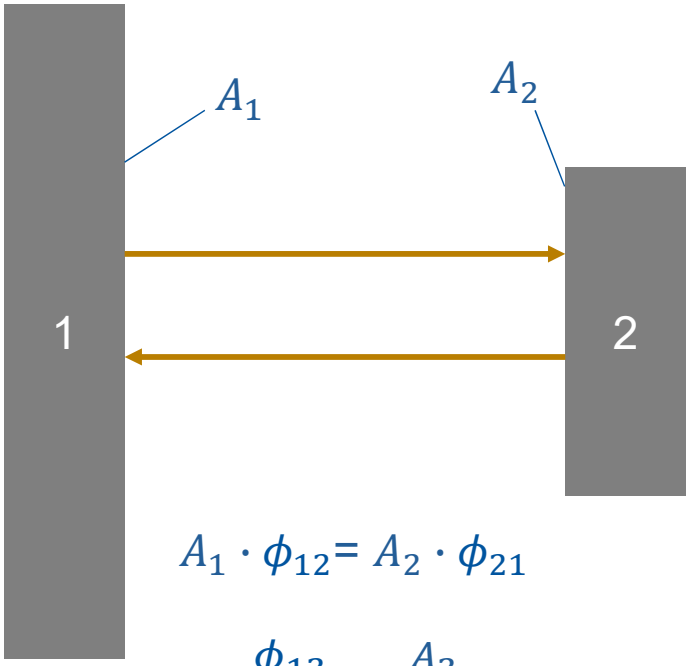
View Factors Cooking Recipe

Reciprocal Rule:

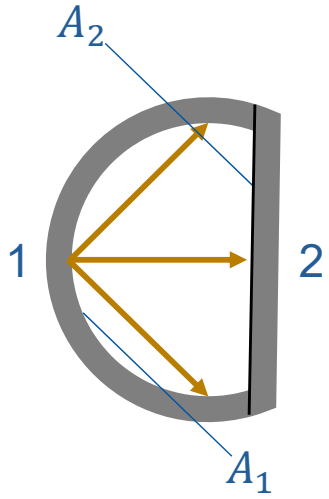
$A_1\phi_{12} = A_2\phi_{21}$

- The product of area times view factor must be the same for two considered surfaces



$$A_1 \cdot \phi_{12} = A_2 \cdot \phi_{21}$$

$$\frac{\phi_{12}}{\phi_{21}} = \frac{A_2}{A_1}$$



$$A_1\phi_{12} = A_2\phi_{21}$$

$$\phi_{21} = 1$$

$$\phi_{12} = \frac{A_2}{A_1}$$

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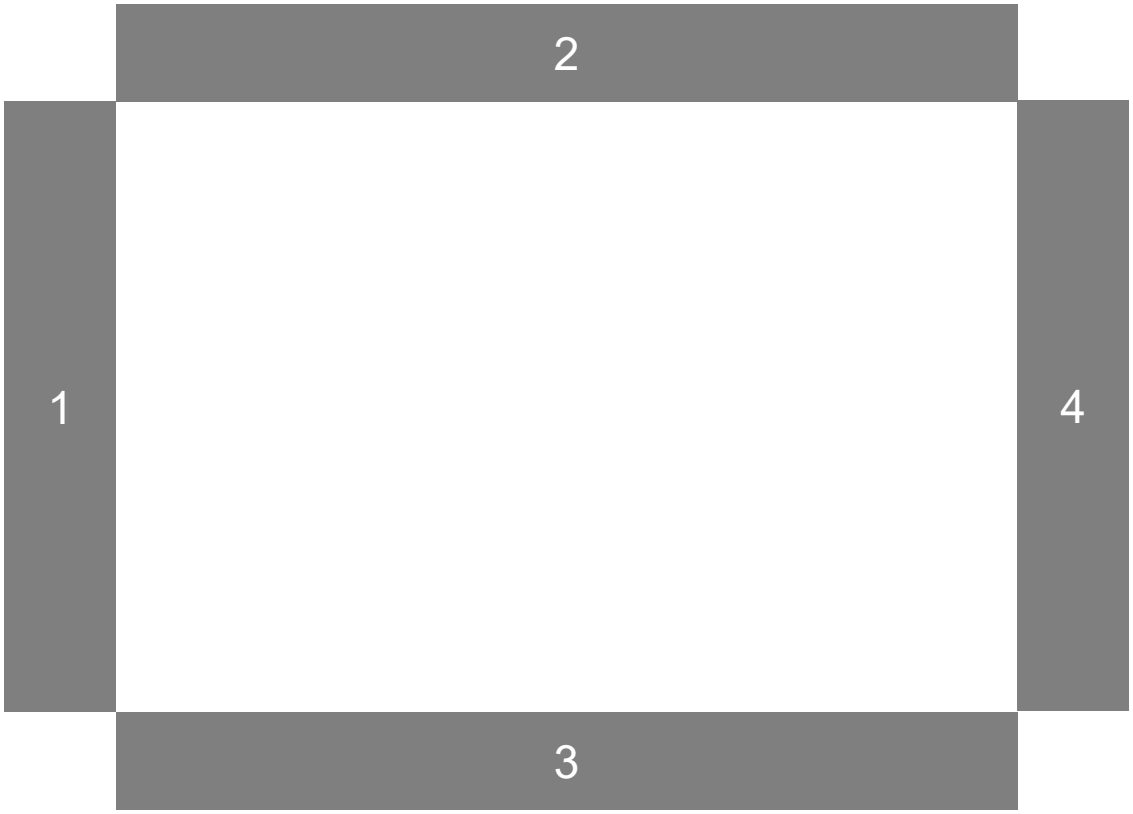
View Factors Cooking Recipe

Symmetry:

- If surface areas are of same size and symmetrically arranged, then the View Factors from the outgoing surface to the individual target surfaces are also identical



$$\phi_{12} = \phi_{13} = \phi_{42} = \phi_{43}$$

$$\phi_{34} = \phi_{31} = \phi_{24} = \phi_{21}$$

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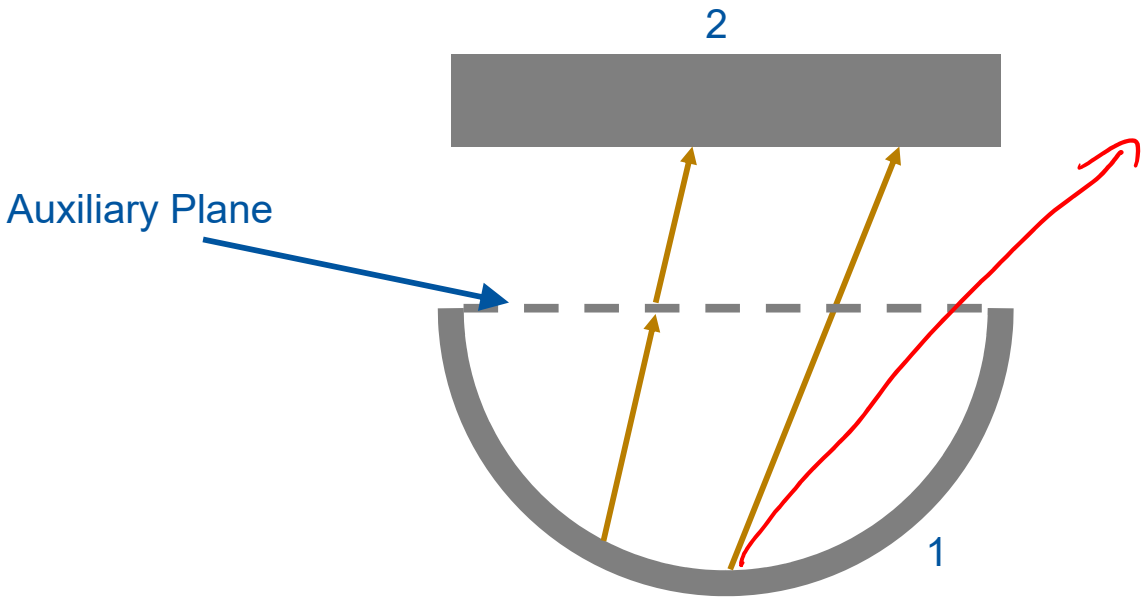
View Factors Cooking Recipe

Auxiliary planes:

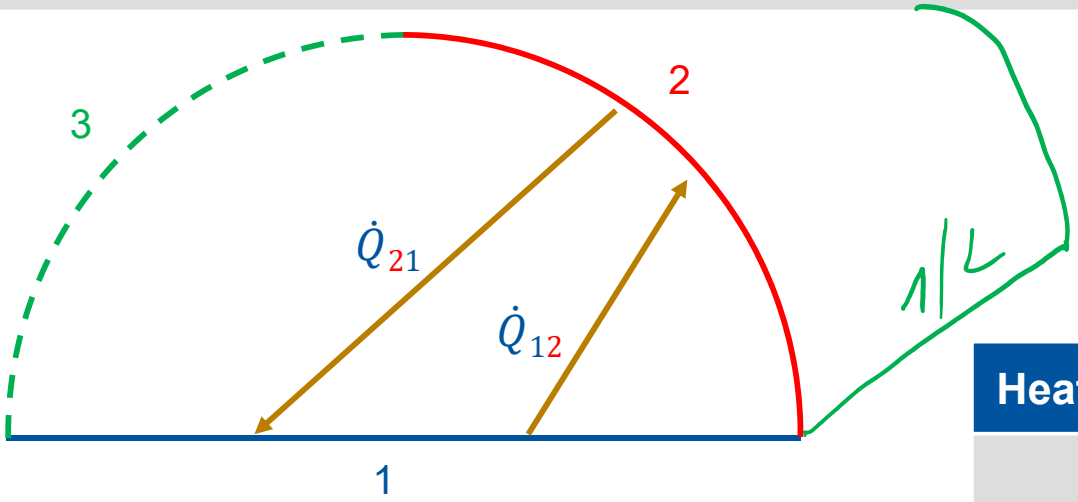
- Smart selection of auxiliary planes helps in dividing a more complicated geometry into simplified geometries



View Factors Exercises

Example 1:

- How much radiation from Area 1 reaches Area 2 and vice versa?



Heat flux 1 to 2:

$$\dot{Q}_{1\to2} = \phi_{12}\, \dot{q}''_1\, A_1$$

Heat flux 2 to 1:

$$\dot{Q}_{2\to1} = \phi_{21}\, \dot{q}''_2\, A_2$$

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View Factors Exercises

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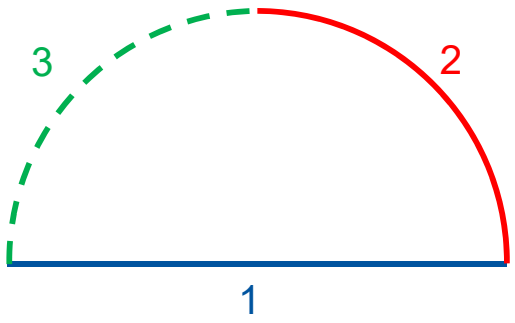

Summation Rule Area 1:

$$\phi_{11} + \phi_{12} + \phi_{13} = 1 \xrightarrow{\phi_{11} = 0} \phi_{12} + \phi_{13} = 1$$

Symmetry Rule Area 1:

$$\phi_{12} = \phi_{13} \longrightarrow \phi_{12} = \frac{1}{2}$$

Reciprocal Rule:

$$\phi_{12}\, A_1 = \phi_{21}\, A_2 \longrightarrow \phi_{21} = \phi_{12} \frac{A_1}{A_2} = \frac{1}{2} \frac{D}{D\frac{\pi}{4}} = \frac{2}{\pi}$$

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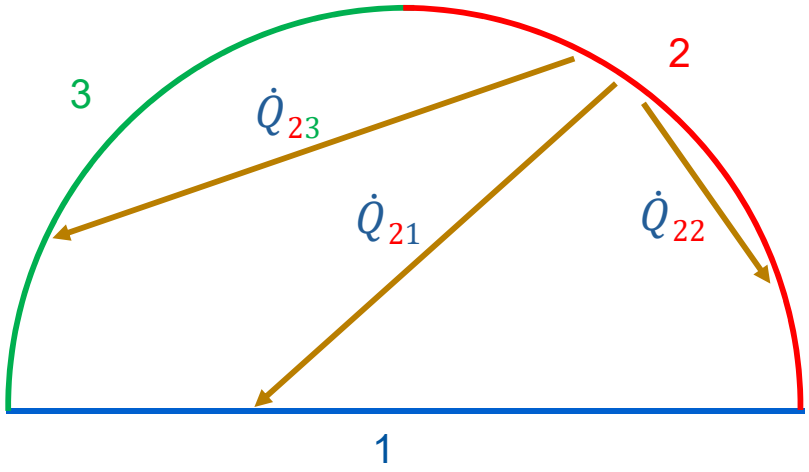
View Factors Exercises

Example 2:

- How much Radiation from Area 2 reaches the Areas 1, 2 and 3?



surface brightness

Heat flux 2 to 1:

$$\dot{Q}_{2\to1} = \Phi_{21}\,\dot{q}''_2\,A_2$$

Heat flux 2 to 2:

$$\dot{Q}_{2\to2} = \Phi_{22}\,\dot{q}''_2\,A_2$$

Heat flux 2 to 3:

$$\dot{Q}_{2\to3} = \Phi_{23}\,\dot{q}''_2\,A_2$$

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View Factors Exercises

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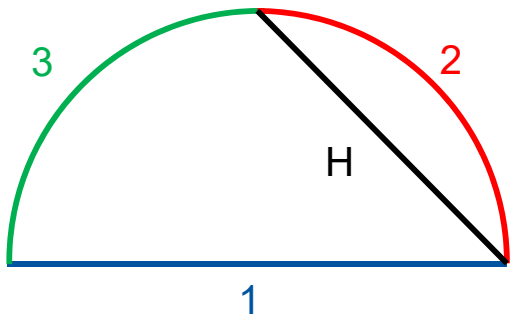


Summation Rule Area 2:

$$\phi_{21} + \phi_{22} + \phi_{23} = 1 \xrightarrow{\phi_{22} \neq 0} \text{Aux. Plane H}$$

Summation Rule Area H:

$$\phi_{H2} + \phi_{HH} = 1 \xrightarrow{\phi_{HH} = 0} \phi_{H2} = 1$$

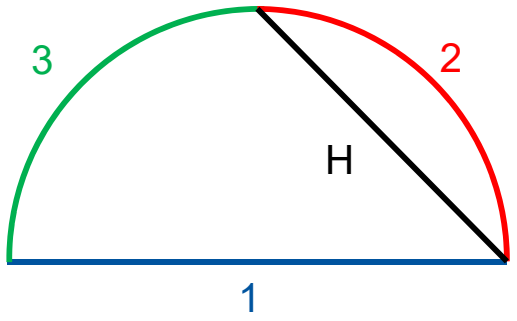
Reciprocal Rule:

$$\phi_{2H}\, A_2 = \phi_{H2}\, A_H \xrightarrow{\phi_{H2} = 1} \phi_{2H} = \frac{A_H}{A_2} = \frac{\frac{D}{\sqrt{2}}}{D\frac{\pi}{4}} = \frac{\sqrt{8}}{\pi}$$

View Factors Exercises

Example 2:

- How much Radiation from Area 2 reaches the Areas 1, 2 and 3?



Summation rule Area 2 with auxiliary plane:

$$\phi_{2H} + \phi_{22} = 1 \longrightarrow \phi_{22} = 1 - \phi_{2H} = 1 - \frac{\sqrt{8}}{\pi}$$

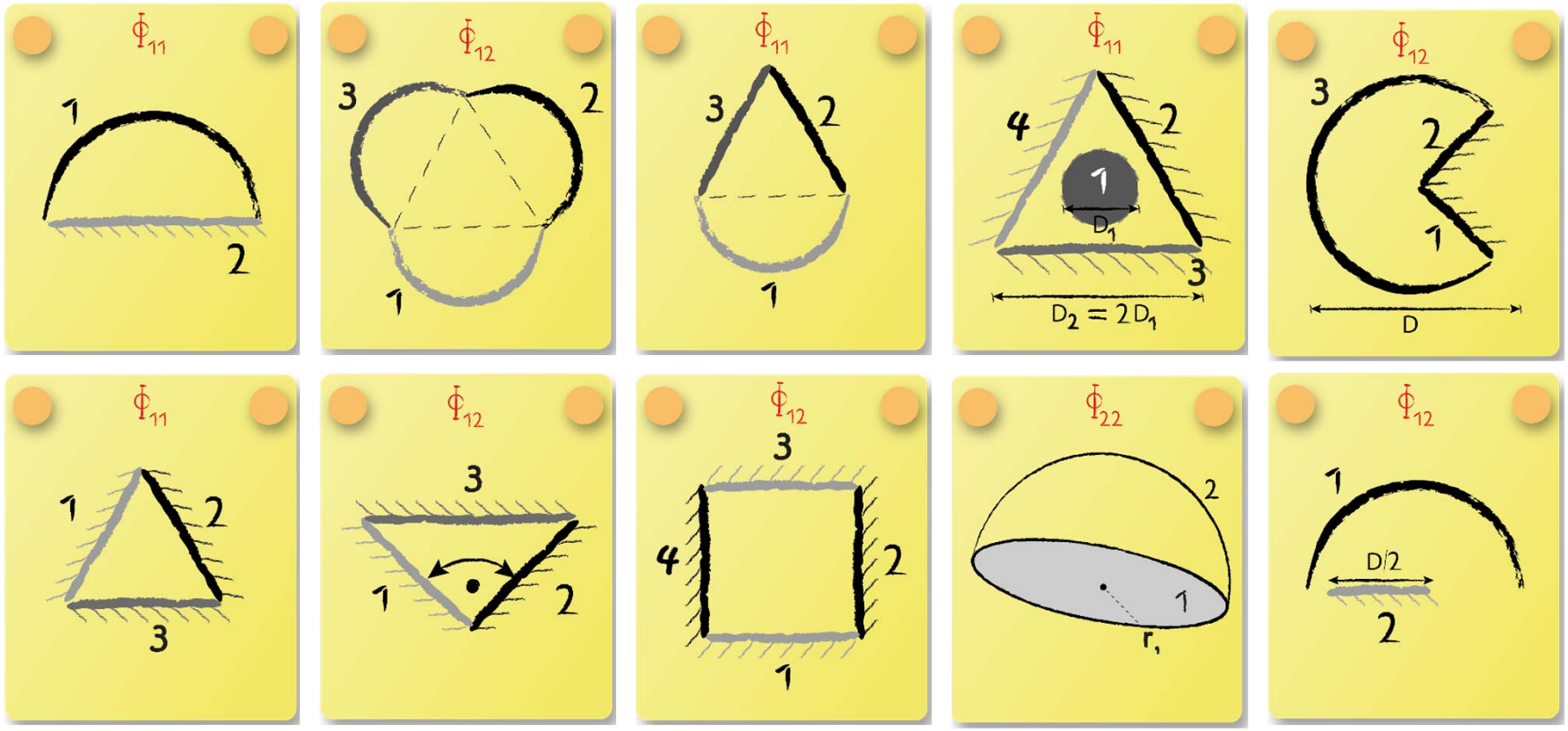
From first Summation rule Area 2:

$$\phi_{23} = 1 - \phi_{22} - \phi_{21} \xrightarrow{\phi_{21} \text{ from Ex. 1}} \phi_{23} = 1 + \frac{\sqrt{8}}{\pi} - 1 - \frac{2}{\pi} = \frac{2(\sqrt{2}-1)}{\pi}$$

View Factors exercises from HeatQuiz App

Example exercises:

- Which values have the respective view factors $\phi_{i,j}$?



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Comprehension questions

Which rules are used for view factor determination?

For which body shapes must $\phi_{i,i}$ be considered?