Heat Transfer: Radiation

View factors

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HEATQUIZ

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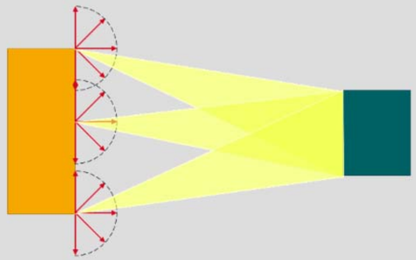
Learning goals

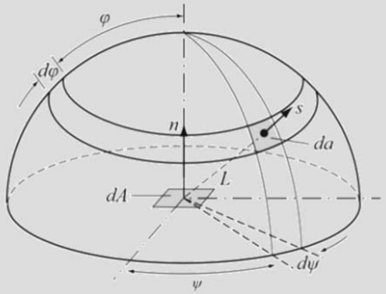
Principle of view factors:

- Understanding of radiated to incident radiation



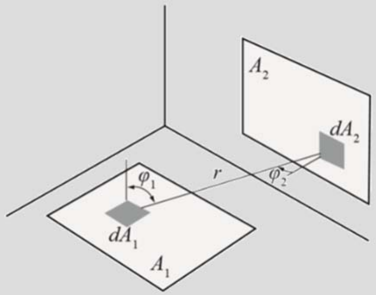
Diffuse Radiation in 3-D Space:

- Understanding of the distribution of radiation irradiating from a surface using an enclosing hemisphere

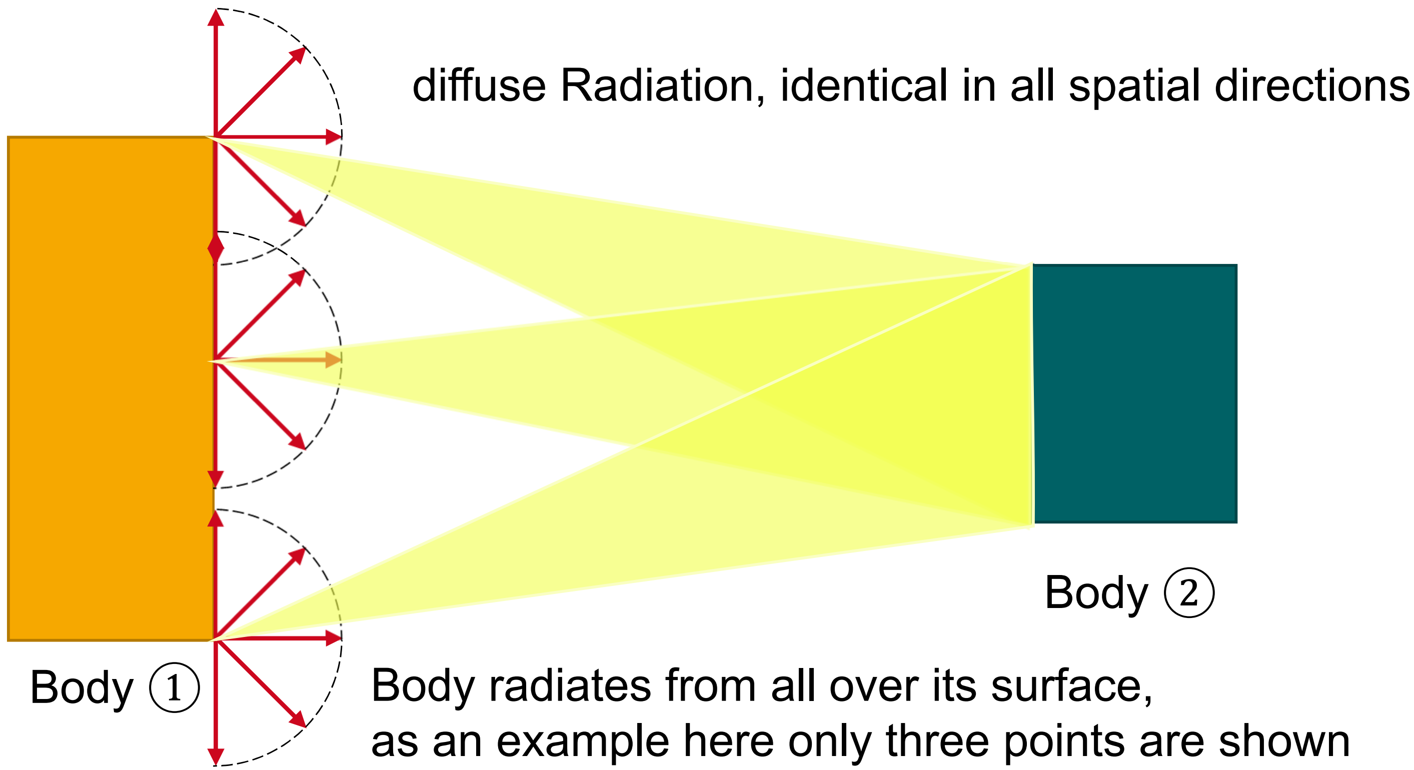


Radiation transfer between two surfaces:

- Ability to determine the View Factors between two surfaces at determined angles



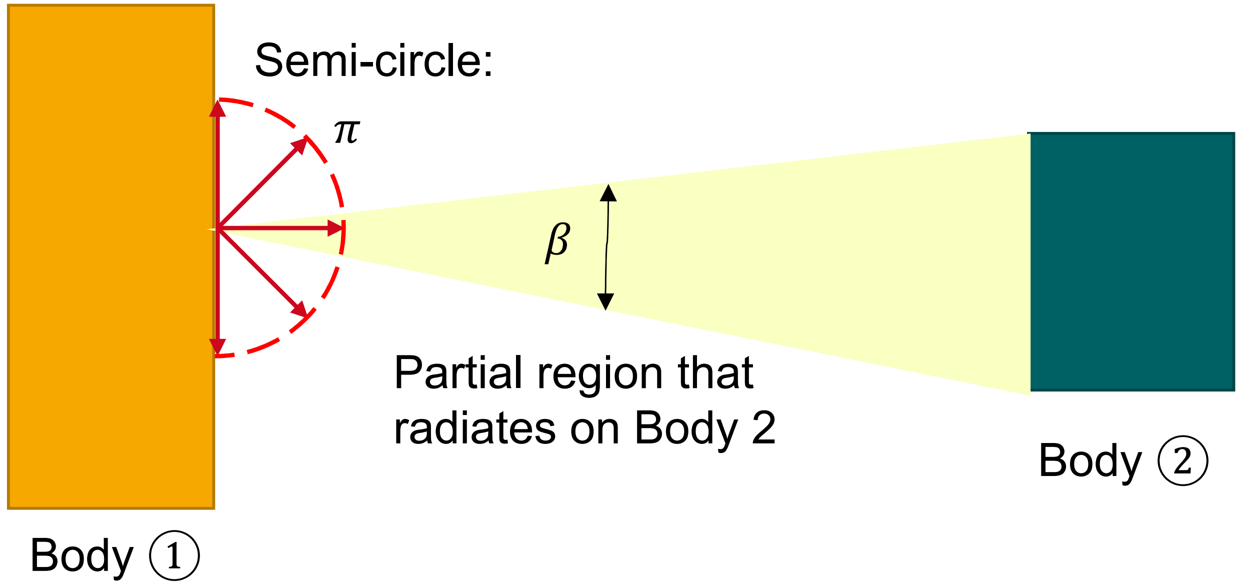
Principle of View Factors



Principle of view factors:

- Which fraction of the diffuse radiation emitted by Body 1 hits Body 2?

Dependencies of the View Factors



Principle of view factors:

1. Definition of the local fraction of the total radiation: β / π
2. Integration over the Surface of Body 1

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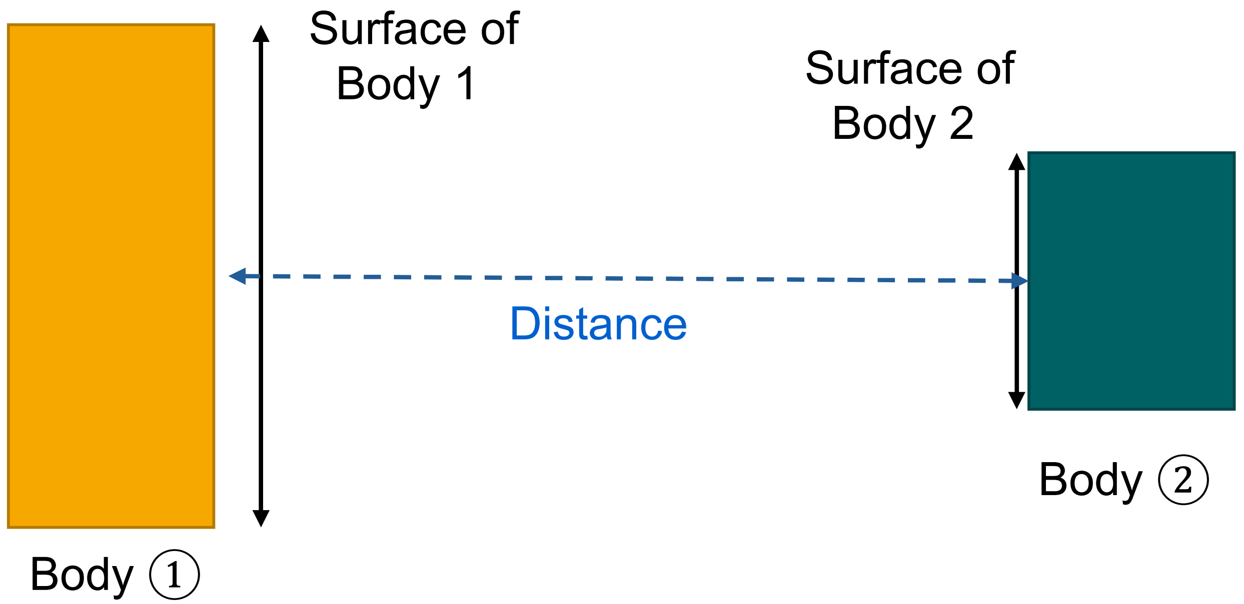
Dependencies of the View Factors



Next step:

- **General definition for the 3-D case**

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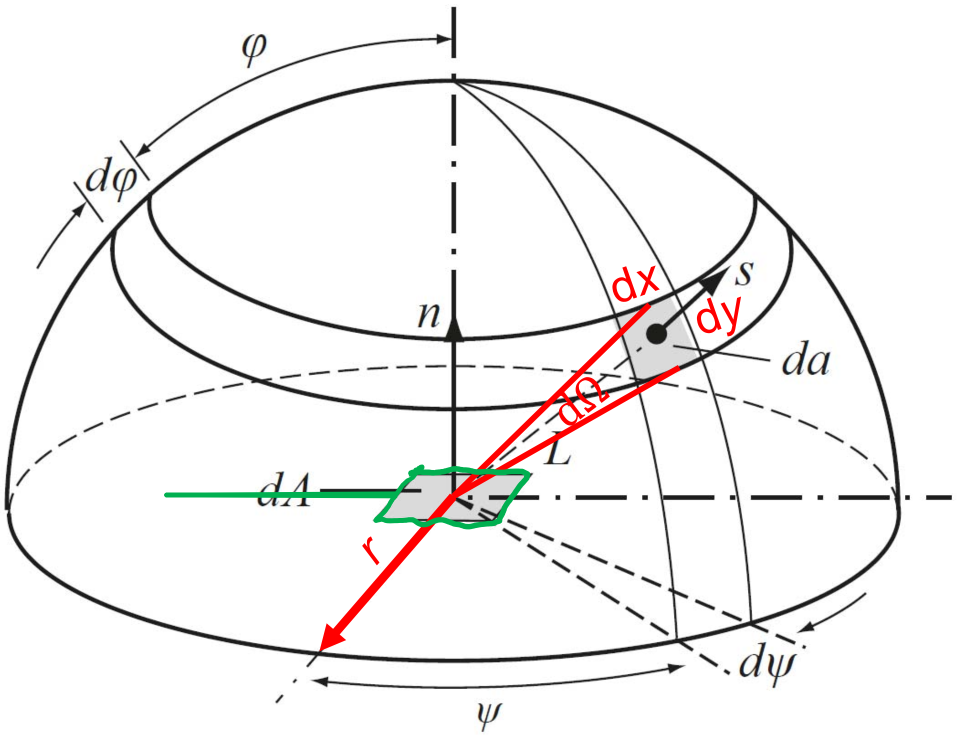
"Power of radiator"

projected area · solid angle

Emitted Radiation of a surface in 3-D space

Question:

Which proportion of the Radiation emitted by **dA** passes through the area element **da** on the hemisphere?



Radiation from surface dA and da:

$$\mathrm{d}x = r \cdot \sin(\varphi) \cdot \mathrm{d}\Psi$$

$$dy = r \cdot \mathrm{d}\,\varphi$$

Solid angle:

$$\mathrm{d}\Omega(\varphi, \Psi) = \frac{r \cdot sin(\varphi) \cdot \mathrm{d}\Psi \cdot r \cdot \mathrm{d}\varphi}{r^2}$$

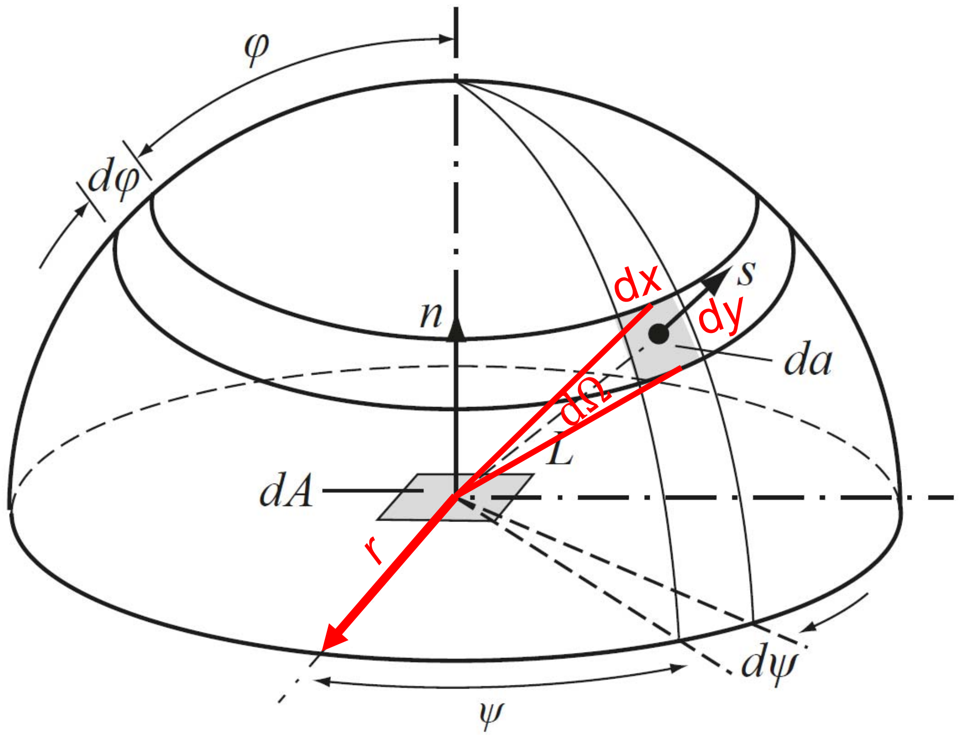
Radiation from **dA** to **da**:

$$\mathrm{d}\dot{Q}(\varphi, \Psi)_{dA \to da} = \overbrace{L}^{\text{Radiance}} \cdot \mathrm{d}\Omega \cdot \overbrace{dA \cdot cos(\varphi)}^{\text{in Radiation direction}}$$

diffuse radiation

$$\int_{\text{Hemisph.}} \frac{\mathrm{d}\dot{Q}}{dA} = \int \mathrm{L} \cdot cos(\varphi) \cdot \mathrm{d}\Omega$$

Emitted Radiation of a surface in 3-D space



Radiation from surface d*A* and da:

$$\mathrm{d}x = r \cdot \sin(\varphi) \cdot \mathrm{d}\Psi$$

$$dy = r \cdot \mathrm{d}\,\varphi$$

Solid angle:

$$\mathrm{d}\Omega(\varphi, \Psi) = \frac{r \cdot sin(\varphi) \cdot \mathrm{d}\Psi \cdot r \cdot \mathrm{d}\varphi}{r^2}$$

Radiation from **dA** to **da**:

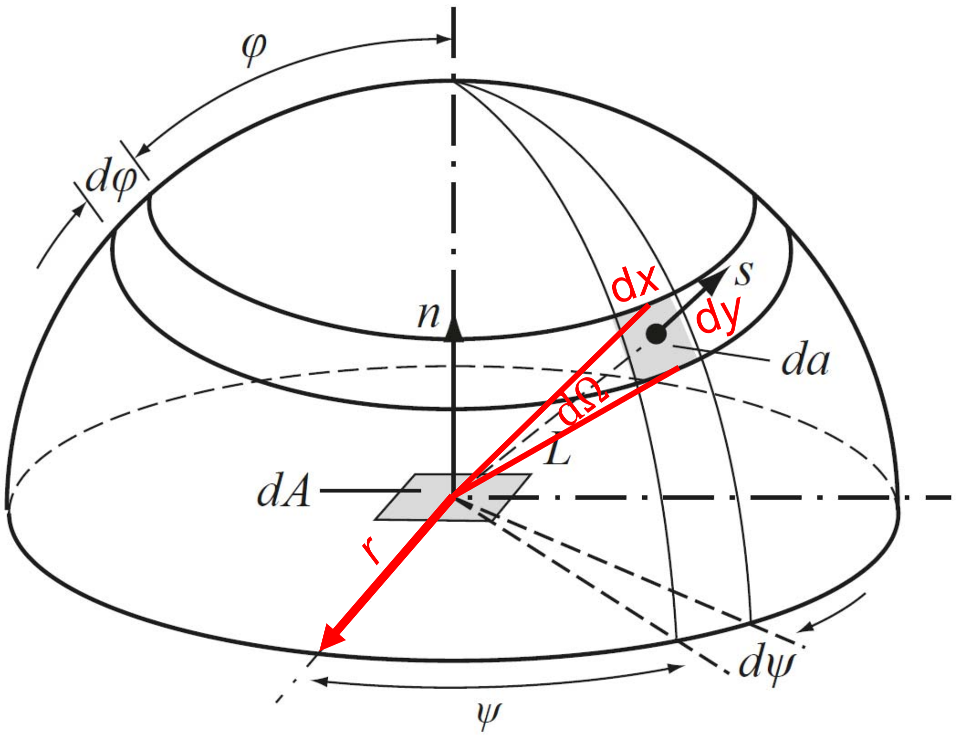
$$\mathrm{d}\dot{Q}(\varphi, \Psi)_{\mathrm{d}A \to \mathrm{da}} = \overbrace{L}^{\text{Radi-ance}} \cdot \mathrm{d}\Omega \cdot \overbrace{\mathrm{d}A \cdot cos(\varphi)}^{\text{in Radiation direction}}$$

$$\int_{\text{Hemisph.}} \frac{\mathrm{d}\dot{Q}}{dA} = \int \mathrm{L} \cdot cos(\varphi) \cdot \mathrm{d}\Omega$$

diffuse radiation

$$\equiv \dot{q}''_{Hem} = L \int_{\Psi=0}^{2\pi} \int_{\varphi=0}^{\pi/2} \sin(\varphi) cos(\varphi) \mathrm{d}\varphi \mathrm{d}\Psi$$

Emitted Radiation of a surface in 3-D space



Radiation from Area d*A* and da:

$$\equiv \dot{q}''_{Hem} = L \int_{\Psi=0}^{2\pi} \int_{\varphi=0}^{\pi/2} \sin(\varphi) cos(\varphi) \mathrm{d}\varphi \mathrm{d}\Psi$$

$$\int_{\varphi=0}^{\pi/2} \sin(\varphi)\, cos(\varphi) \mathrm{d}\varphi = \frac{1}{2} \cdot \sin^2(\varphi)\Big|_0^{\frac{\pi}{2}} = \frac{1}{2}$$

$$\int_{\Psi=0}^{2\pi} \frac{1}{2} \mathrm{d}\Psi = \frac{1}{2} \Psi \Big|_0^{2\pi} = \pi$$

$$\dot{q}''_{Hem} = \pi \cdot L$$

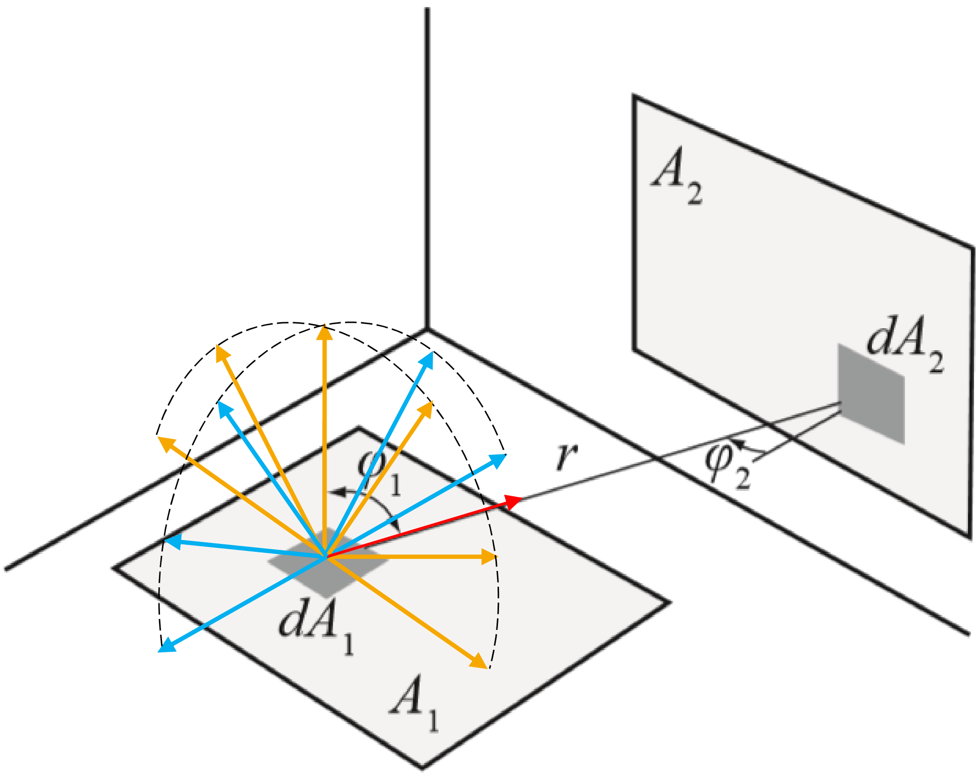
diffuse radiation

$$L = \frac{\dot{q}''}{\pi}$$

$\boxed{\dot{q}'' \cdot A}$

surface brightness

Radiation transfer between two surfaces



Radiation from Area dA_1 and dA_2 :

$$d\dot{Q}_{1\to2} = L_1 \cos\varphi_1 \, dA_1 d\Omega$$

$$d\Omega = \frac{dA_2 \cos\varphi_2}{r^2}$$

diffuse

$$L_1 = \frac{\dot{q}_1''}{\pi}$$

$$\dot{Q}_{1\to2} = \frac{\dot{q}_1''}{\pi} \boxed{\int\int \frac{\cos\varphi_1 \cos\varphi_2}{r^2} dA_1 \, dA_2}$$

$$\dot{Q}_{2\to1} = \frac{\dot{q}_2''}{\pi} \boxed{\int\int \frac{\cos\varphi_2 \cos\varphi_1}{r^2} dA_2 \, dA_1}$$

Geometrical component identical

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Radiation transfer between two surfaces

$$= \frac{\dot{q}_1''}{\pi} \int\int \frac{\cos\varphi_1 \, \cos\varphi_2}{r^2} \, dA_1$$

on view factor:

$$_2 = \frac{\begin{pmatrix}\text{Radiation sent from 1} \\ \text{in direction 2}\end{pmatrix}}{\begin{pmatrix}\text{Total Radiation} \\ \text{emitted from 1}\end{pmatrix}} = \frac{\dot{Q}_1}{\dot{q}_1''}$$

Radiation from Area 1 to Area 2:

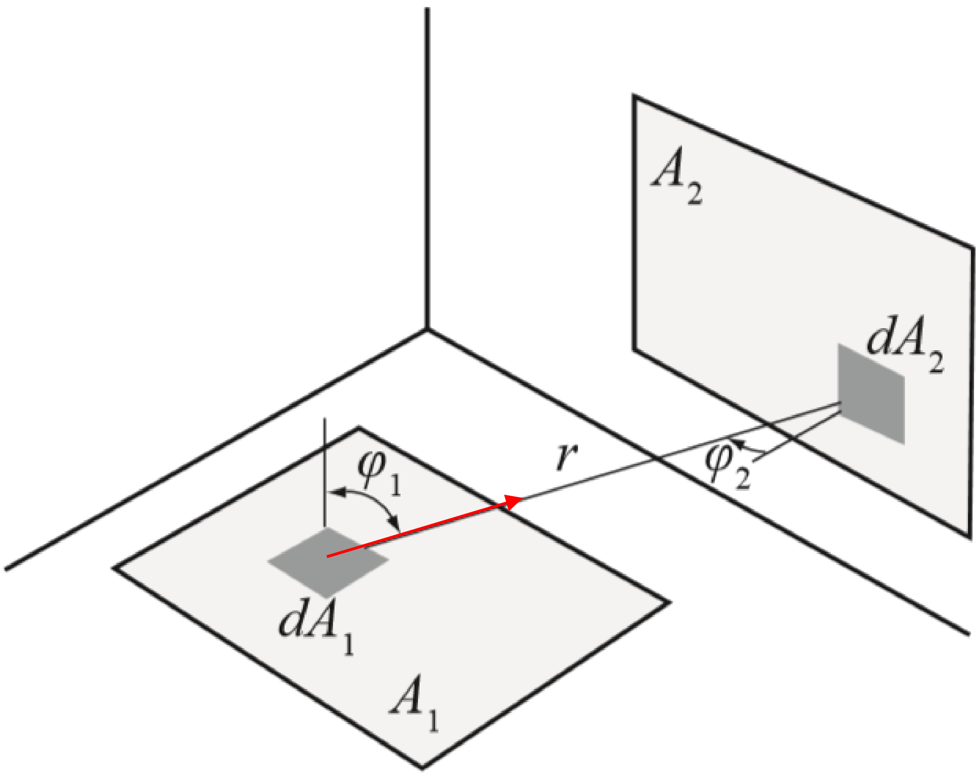
$$\dot{Q}_{1\rightarrow 2} = \frac{\dot{q}_1''}{\pi} \int\int \frac{\cos\varphi_1 \, \cos\varphi_2}{r^2} \, dA_1 \, dA_2$$

Definition view factor:

$$\phi_{12} = \frac{\begin{pmatrix}\text{Radiation sent from 1} \\ \text{in direction 2}\end{pmatrix}}{\begin{pmatrix}\text{Total Radiation} \\ \text{emitted from 1}\end{pmatrix}} = \frac{\dot{Q}_{1\rightarrow 2}}{\dot{q}_1'' \, A_1}$$

$$\phi_{12} = \frac{1}{A_1} \int\int \frac{\cos\varphi_1 \, \cos\varphi_2}{\pi r^2} \, dA_1 \, dA_2$$

Radiation transfer between two surfaces



Radiation exchange of Area 1 and Area 2:

$$\dot{Q}_{1\rightarrow 2} = \frac{\dot{q}_1''}{\pi} \boxed{\int\int \frac{\cos\varphi_1 \, \cos\varphi_2}{r^2} \, dA_1 \, dA_2}$$

$$\dot{Q}_{2\rightarrow 1} = \frac{\dot{q}_2''}{\pi} \boxed{\int\int \frac{\cos\varphi_2 \, \cos\varphi_1}{r^2} \, dA_2 \, dA_1}$$

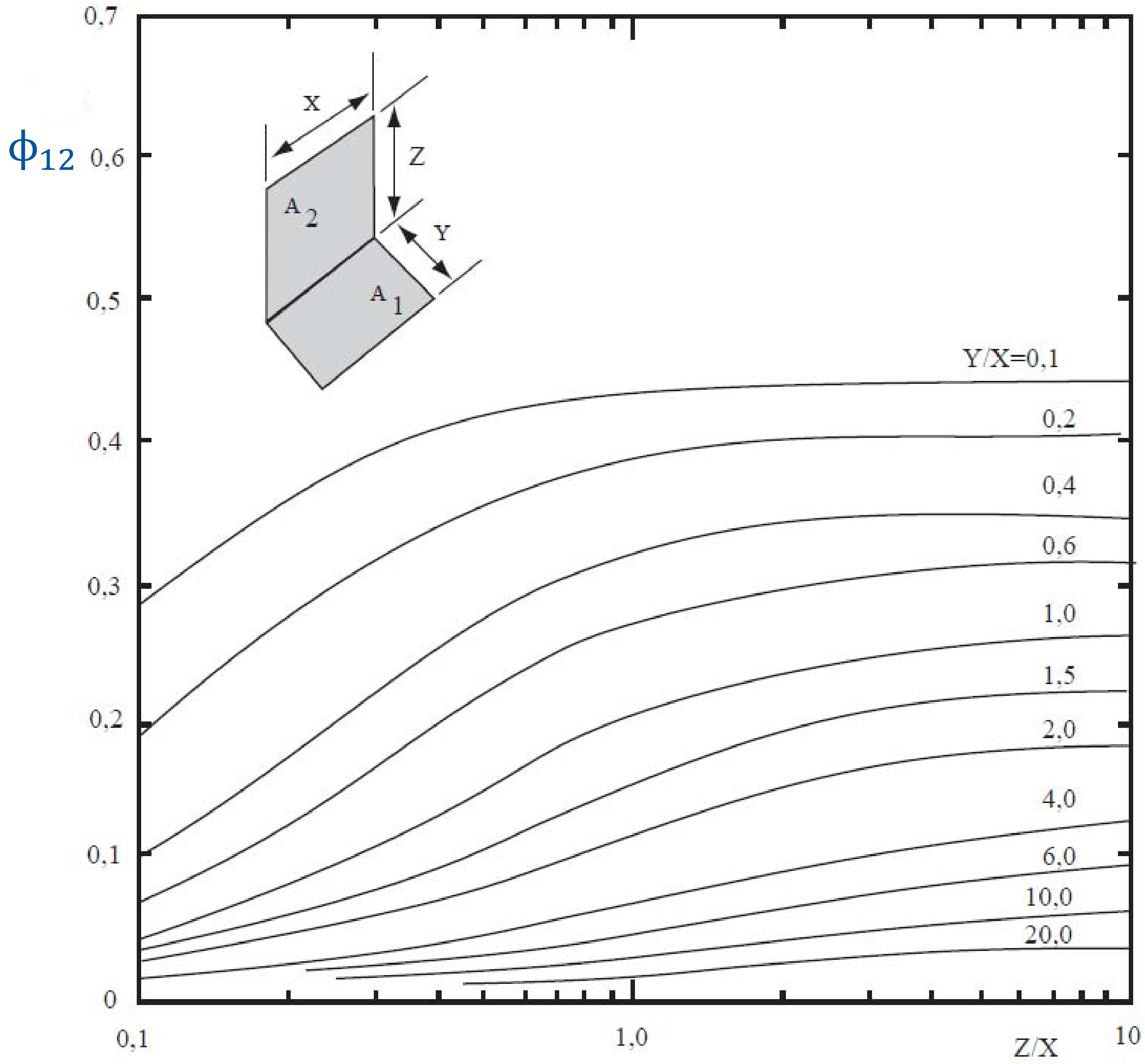
Geometrical component identical

$$\frac{\dot{Q}_{1\rightarrow 2}}{\dot{Q}_{2\rightarrow 1}} = \frac{\dot{q}_1''}{\dot{q}_2''}$$ and $$\phi_{12} = \frac{\dot{Q}_{1\rightarrow 2}}{\dot{q}_1'' \, A_1}$$

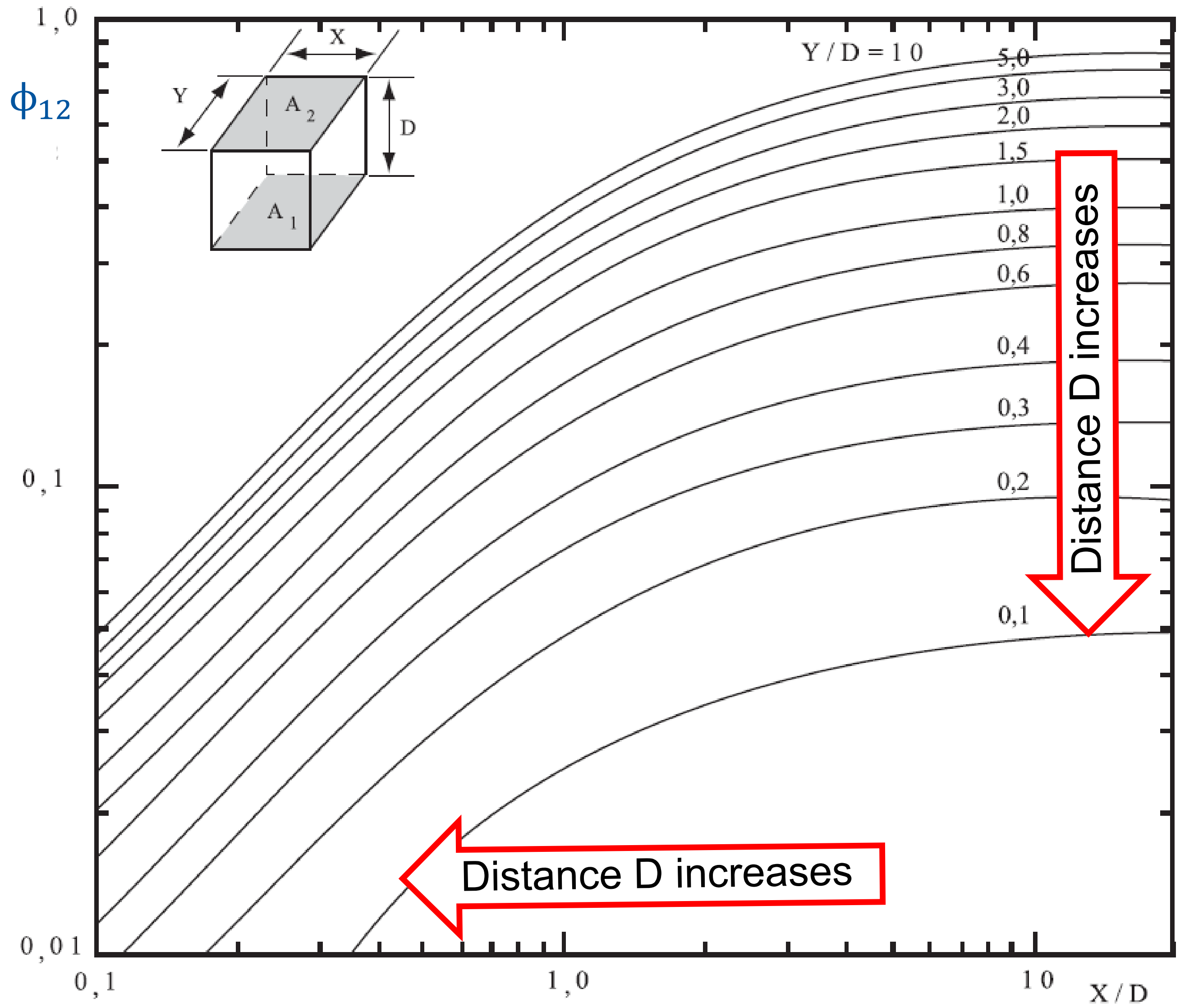
$$\phi_{12} A_1 = \frac{\dot{Q}_{1\rightarrow 2}}{\dot{q}_1''} = \frac{\dot{Q}_{2\rightarrow 1}}{\dot{q}_2''} = \phi_{21} A_2$$

Reciprocal rule: $\phi_{12} A_1 = \phi_{21} A_2$

View Factors of rectangular surfaces (formulary)



View Factors of opposite surfaces (formulary)



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Comprehension questions

Which parameters of radiation emerging from a surface are included in/ described by the view factor concept?

Calculation of radiation exchange by using visual factors ⇨ valid also, if the bodies radiate directionally?

In general, what are view factors depending on?