Heat Transfer: Radiation

Surface brightness
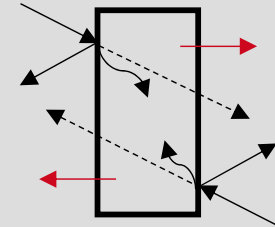
<u>Prof. Dr.-Ing. Reinhold Kneer</u>

Prof. Dr.-Ing. Dr. rer. pol. Wilko Rohlfs

HEATQUIZ

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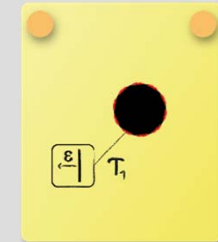
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Learning goals

Surface brightness:

▶ Understanding of Surface Brightness and its meaning

HeatQuiz:

▶ Learn and practice to formulate the Surface Brightness of Bodies and System of bodies
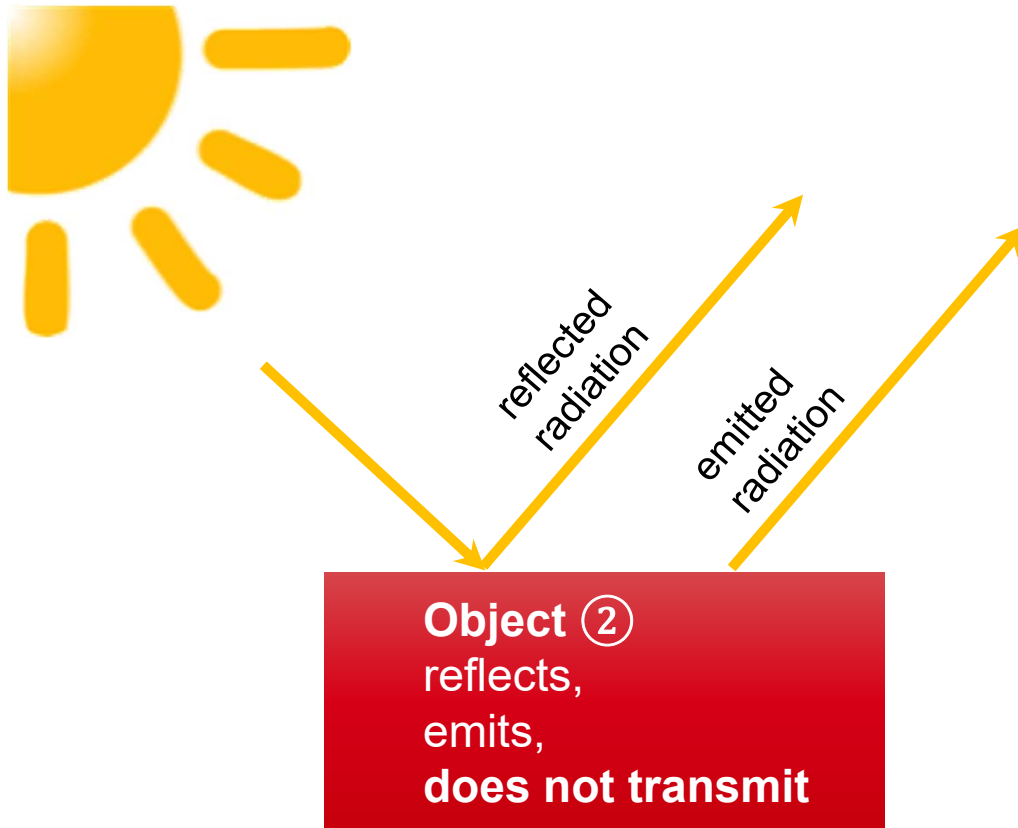
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Surface brightness

Surface brightness:

Total Radiation flux of a surface:

- Sum of reflection, transmission and emission

$\rightarrow$ Example: Window pane

reflected radiation

transmitted radiation

emitted radiation

Object ①
reflects,
emits,
transmits

only this term carries object ① surface temperature information

...era
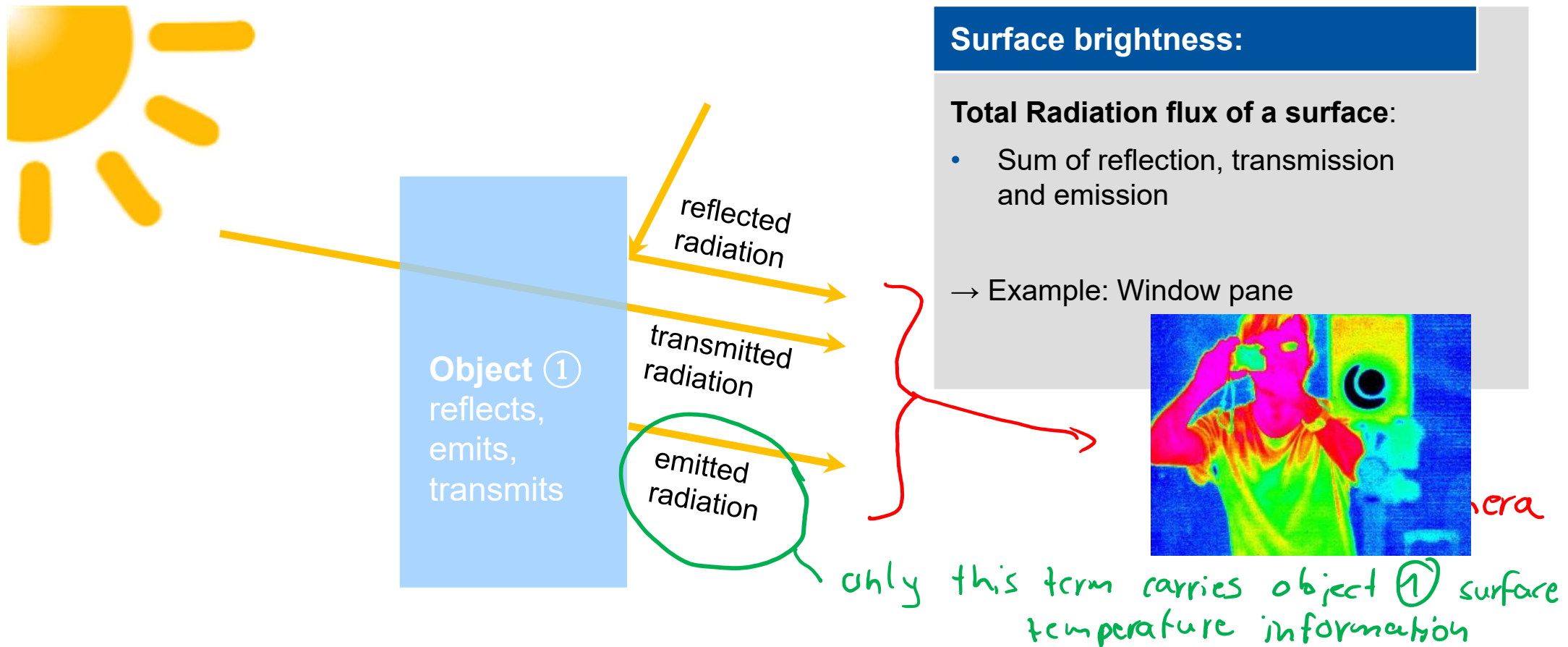
Surface brightness – Object ①, right:

$$\dot{Q}_{1,\text{right}} = \text{Emission} + \text{Reflection} + \text{Transmission}$$

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Surface brightness

reflected radiation

emitted radiation

Object ②
reflects,
emits,
does not transmit

Surface brightness:
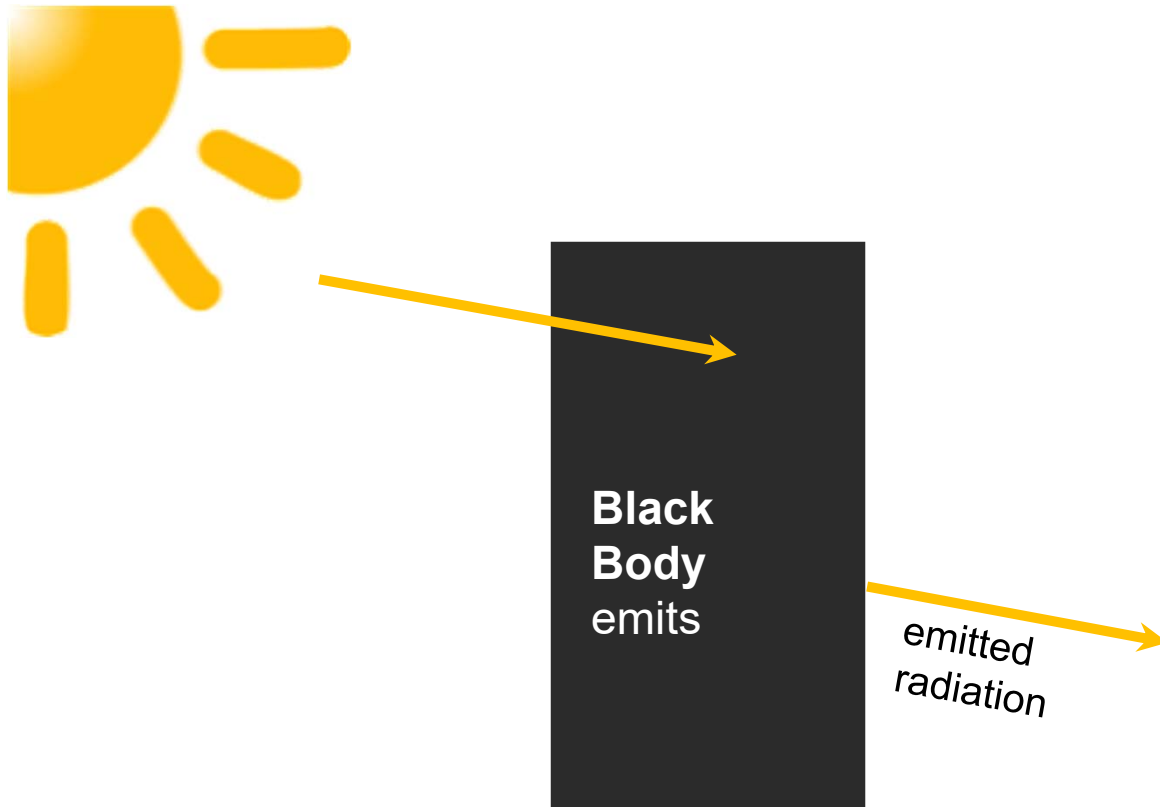
Total Radiation flux of a surface:

- Sum of reflection and emission
- **no transmission**

→ Example: Rigid body of steel, concrete

Surface brightness – Object ② :

$$\dot{Q}_2 = \text{Emission} + \text{Reflection}$$

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Surface brightness

Black Body emits

emitted radiation

Surface brightness:

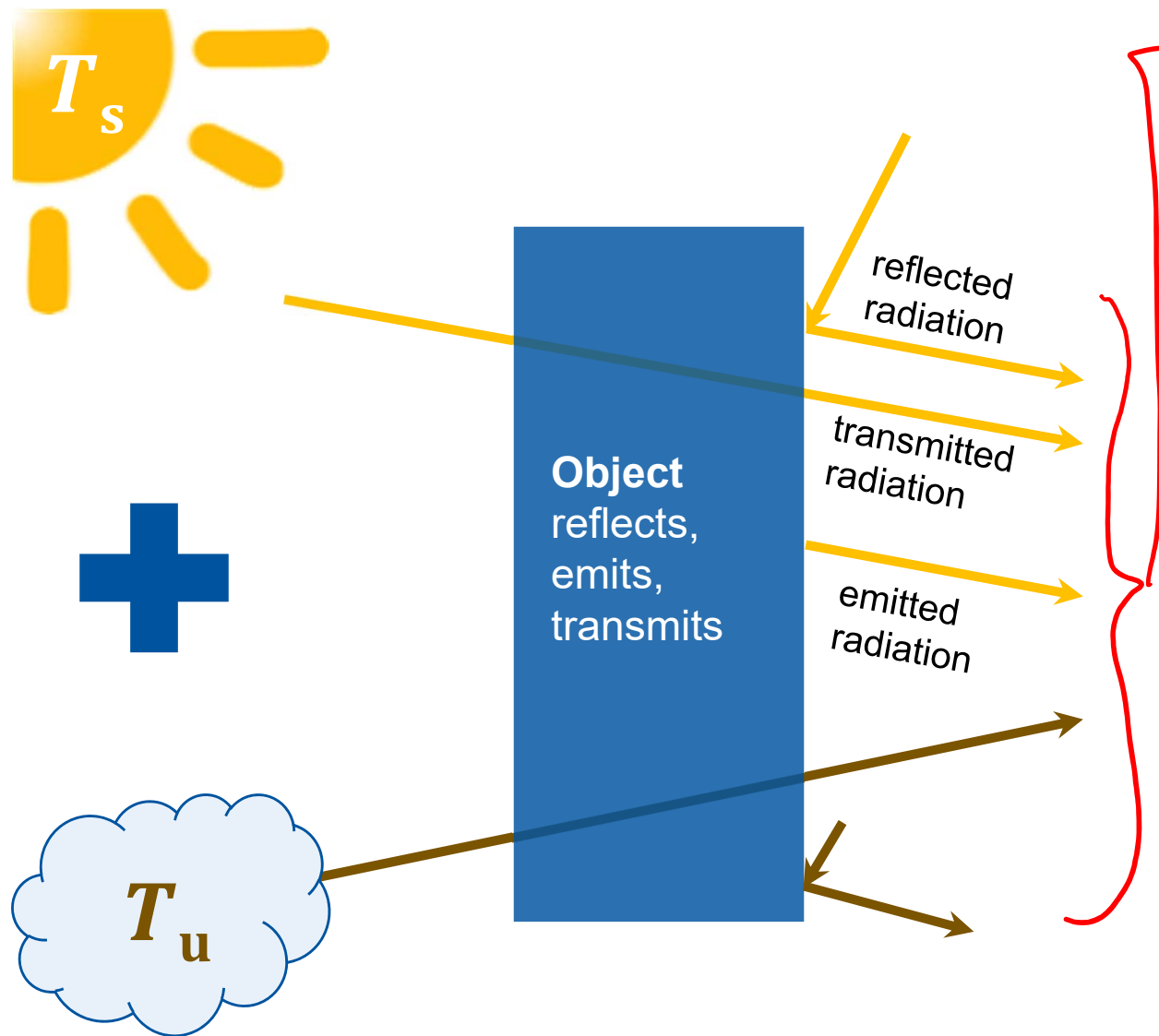**Total Radiation flux of a black body:**

- Emission

- **no reflection and transmission**

$\rightarrow$ Example: Cavity

Surface brightness – Black Body:

$$\dot{Q}_S = \text{Emission}$$

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Surface brightness with more radiation sources

Surface brightness:

Total Radiation flux from object:

- Sum of reflection, transmission and emission
- **From all radiation sources**

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Surface brightness with spectral object characteristics

spectral characteristics Object

Spectral consideration:

Divide the incident radiation into two regions:

$$\text{I} \quad 0 \quad \rightarrow \quad \lambda_1$$
$$\text{II} \quad \lambda_1 \quad \rightarrow \quad \infty$$

Object spectral characteristics

"short wave" "long wave"

T_s

λ_1

Intensity

Wavelength λ

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Surface brightness with spectral object characteristics

spectral characteristics Object

Spectral consideration:

Divide the incident radiation into two regions:

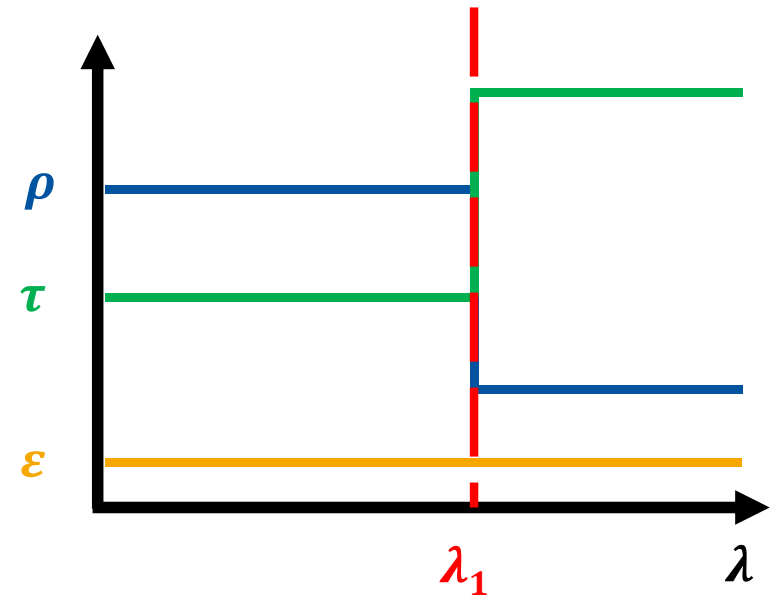$$\text{I} \quad 0 \quad \rightarrow \quad \lambda_1$$
$$\text{II} \quad \lambda_1 \quad \rightarrow \quad \infty$$

short wave $0 \rightarrow \lambda_1$

+

long wave $\lambda_1 \rightarrow \infty$

Object spectral characteristics

ρ

τ

ε

λ_1

λ

Surface brightness:

Total Radiation flux from object:

- Sum of reflection, transmission and emission

- **Separate consideration of all wavelength regions + superposition**

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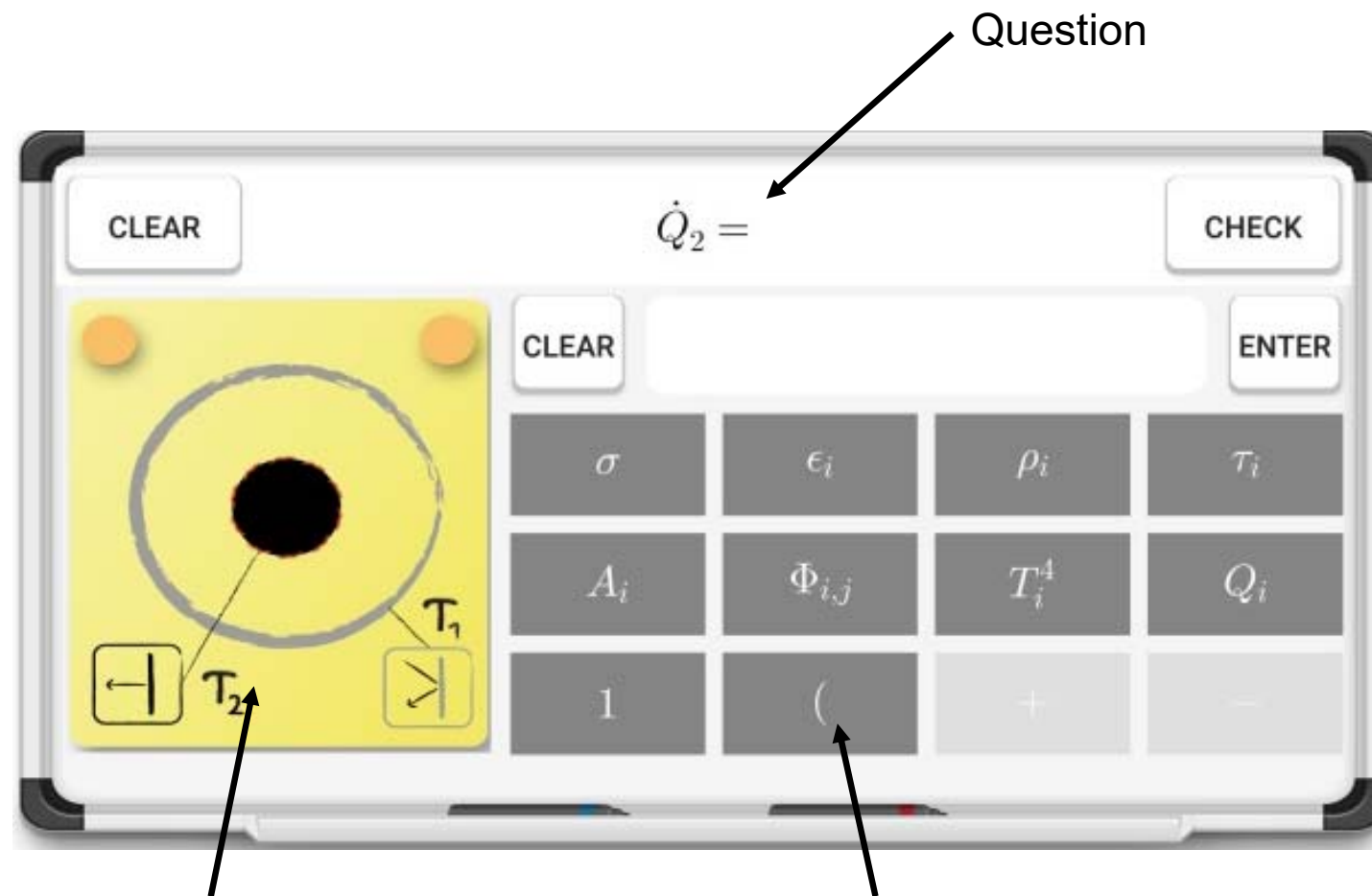
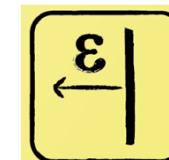RWTH AACHEN UNIVERSITY

HeatQuiz: Surface brightness
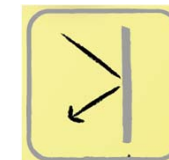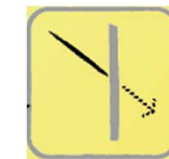

Question

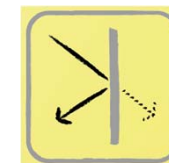Illustration of the task

Input keyboard

Black Body
only Emission

Grey Body
Emission and Reflection
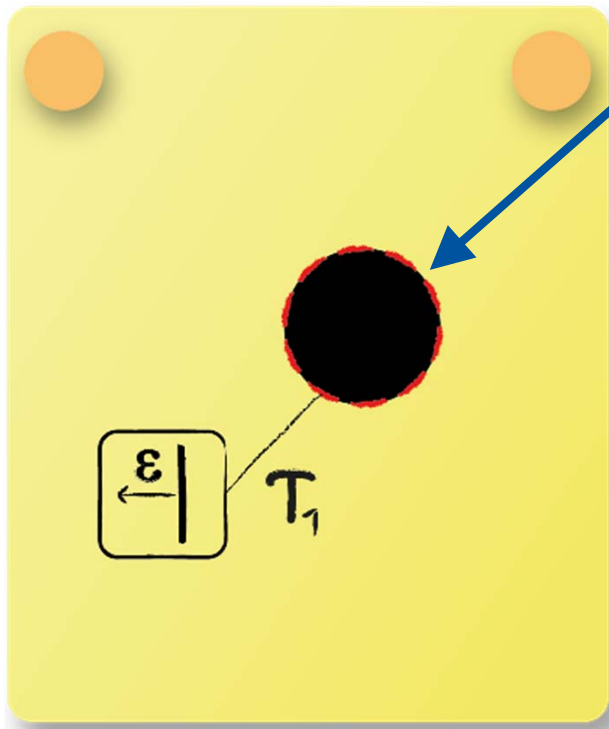
Grey Body
Emission and Transmission

Grey Body
Emission, Reflection
and Transmission

Each body with T > 0 K
emits Radiation!

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Black Body:

▶ **Only consider own emission**

$$\dot{Q}_1 = \text{Emission} + \cancel{\text{Reflection}} + \cancel{\text{Transmission}}$$

Solution:

$$\dot{Q}_1 = A_1 \varepsilon_1 \sigma T_1^4$$

Or alternatively, because $\varepsilon_1 = 1$:

$$\dot{Q}_1 = A_1 \sigma T_1^4$$

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Grey Body:

▶ **Own emission and reflection are considered**

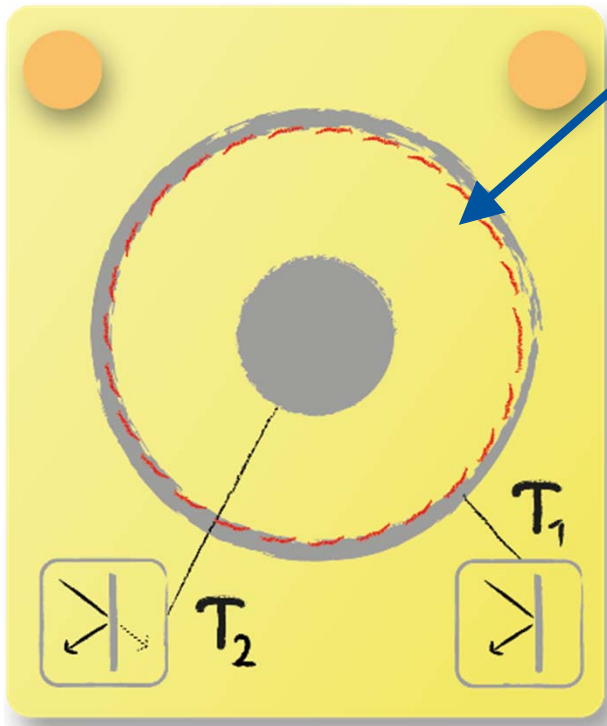$$\dot{Q}_1 = \text{Emission} + \text{Reflection} + \text{Transmission}$$

Solution:

$$\dot{Q}_1 = A_1 \varepsilon_1 \sigma T_1^4 + \rho_1 \left(\phi_{11} \dot{Q}_1 + \phi_{21} \dot{Q}_2 \right)$$

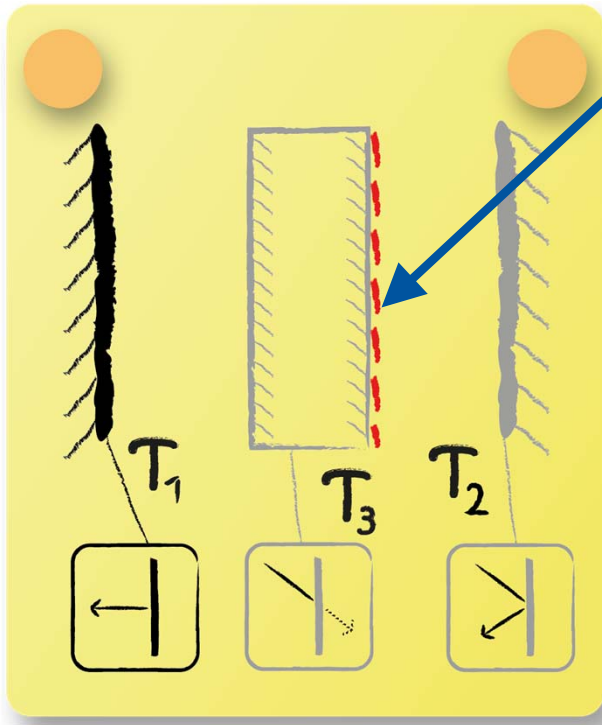$$\dot{Q}_2 = A_2 \varepsilon_2 \sigma T_2^4 + \rho_2 \phi_{12} \dot{Q}_1 + \tau_2 \phi_{12} \dot{Q}_1$$

Systematic setting up of the surface brightness:

Use of View Factors: ϕ_{11} (evaluate separately, do not insert into equation here)

Implicit setting up using Surface Brightness ($\dot{Q}_1$, $\dot{Q}_2$)

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HeatQuiz: Surface Brightness of a transparent body

Transparent Body:

► Own emission and Transmission to be considered

► Here the surface brightness of the right side of the body is to be determined

$$\dot{Q}_1^{3r} = \text{Emission} + \text{Reflection} + \text{Transmission}$$

Solution:

$$\dot{Q}_{3,r} = A_{3,r}\varepsilon_3\sigma T_3^4 + \rho_3\big(\phi_{23}\dot{Q}_2\big) + \tau_3\big(\phi_{13}\dot{Q}_1\big)$$

$$\rho_3 = 0$$

$$\dot{Q}_1 = A_1\varepsilon_1\sigma T_1^4$$

$$\dot{Q}_2 = A_2\varepsilon_2\sigma T_2^4 + \rho_2\big(\phi_{32}\dot{Q}_{3,r}\big)$$

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Comprehension Questions

How can Surface Brightness be interpreted physically?

Which principles should be observed when setting up Surface Brightness?

Why is infrared measurement of surface temperatures difficult? Which part of Surface Brightness carries this information?

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