Heat Transfer: Learning Path Radiation

Nomenclature

Subscript:

η	Wavenumber-specific	
λ	Wavelength-specific	
0	Incident radiation	
s	Black Body	
$\mathrm{i} \rightarrow \mathrm{j}$	From object *i* to object *j*	

Superscript:

$''$	Area-related	
$'''$	Volume-related	
$\dot{}$	Time derivative (heat flux, mass flow, enthalpy flow etc.)	

Blackbody:

λ	Wavelength of the radiation	$[\mathrm{m}]$
ν	Frequency of radiation	$[\mathrm{s}^{-1}]$
σ	Stefan-Boltzmann-Constant	$[\mathrm{W/(m^2K^4)}]$
c	Speed of Light	$[\mathrm{m/s}]$
E	Energy of a photon	$[\mathrm{J}]$
$\mathrm{F}(\lambda)$	Radiation fraction	[-]
h	Planck constant	$[\mathrm{Js}]$
$\dot{q}''_{\mathrm{s},\lambda}$	Spectral radiant flux density of a black body	$[\mathrm{W/(m^2m)}]$

Real objects:

α	Absorptivity	[-]
ε	Emissivity	[-]
ρ	Reflectivity	[-]
τ	Transmissivity	[-]
φ	Viewing angle	$[\mathrm{rad}]$

View factors:

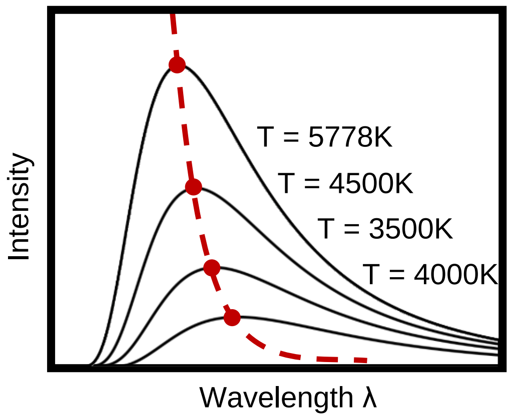
Φ_{ij}	View factor from object *i* to object *j*	[-]
Ω	Solid angle	$[\mathrm{rad}]$
L	Radiant flux density	$[\mathrm{W/m^2}]$
$\dot{Q}_{\mathrm{i}\rightarrow\mathrm{j}}$	Radiation from surface of a body *i* to *j*	$[\mathrm{W}]$

Heat Transfer: Learning Path Radiation

L01: Black Body Radiation

Learning goals:

- Understanding of the Wave-Quantum Duality
- Black Body: Description of the spectral radiation intensity according to Planck
- Solution approach for integration of the Planck's Distribution Law
- Use of Stefan-Boltzmann Law
- Relationship from temperature and position of maximum spectral radiation intensity



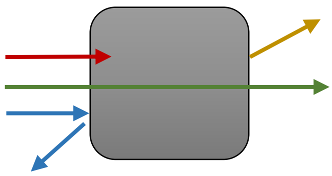
Comprehension questions:

- ☐ What is a “Black Body“?
- ☐ Which assumptions are valid for the calculation of “Black bodies“?
- ☐ Which law can be used to determine the wavelength at the intensity maximum of a “Black bodies“?
- ☐ Which approach was used to determine the Stefan-Boltzmann constant?
- ☐ How can the radiation intensity in a certain wavelength range $\lambda_1 - \lambda_2$ be calculated?

L02: Radiation of Real Bodies

Learning goals:

- Definition and interpretation of Emissivity, Absorptivity, Transmissivity and Reflectivity
- Behaviour of real bodies compared to ideal bodies
- Angular dependence of the radiation properties of real bodies



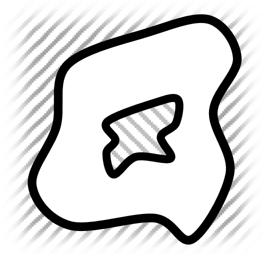
Comprehension questions:

- ☐ In which proportions is divided the radiation that hits a body (real bodies)?
- ☐ What is the difference between black, grey and real bodies (related to wavelength)?

Heat Transfer: Learning Path Radiation

L03: Kirchhoff's Law

Learning goals:



- Relationship between absorptivity and emissivity
- Conditions where "ε = α" (wavelength independent) is valid?

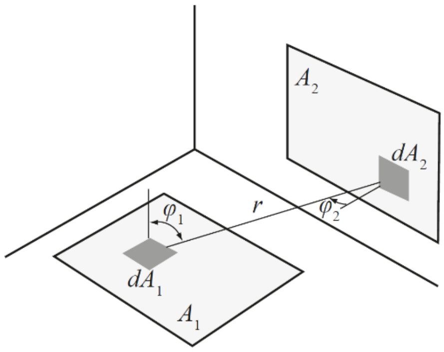
Comprehension questions:

- ☐ In which case can it be assumed that both $\alpha(\lambda) = \varepsilon(\lambda)$ and $\alpha = \varepsilon$ are valid?
- ☐ To which part of radiation does the emissivity refer and to which part the Absorptivity?
- ☐ When $\alpha(\lambda) = \varepsilon(\lambda)$ is valid, is then the absorbed and emitted heat flux identical?

L04: View Factors

Learning goals:

- Understanding of radiated to incident radiation
- Understanding of the distribution of radiation irradiating from a surface using an enclosing hemisphere
- Ability to determine the view factors between two surfaces at determined angles



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?

L05: Calculation Rules of View Factors

Learning goals:

$$\sum_{\mathrm{j}} \phi_{\mathrm{ij}} = 1$$

- Sum of view factors for one object is 1!
- Determine view factors from looking at the opposite surface or object
- Smart usage of symmetry conditions
- Identify meaningful auxiliary planes

$$\xrightarrow{\phi_{\mathrm{ij}}}$$

$$\xleftarrow[\phi_{\mathrm{ji}}]{}$$

Comprehension questions:

- ☐ Which rules are used for view factor determination?
- ☐ For which body shapes must $\phi_{\mathrm{i,i}}$ be considered?

Heat Transfer: Learning Path Radiation

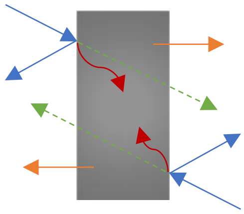
Map 01: View Factors

Learning goals:

- Practicing the calculation of view factors on simple 2- and 3-dimensional geometries

---

L06: Surface Brightness



Learning goals:

- Understanding of Surface Brightness and its meaning
- Learn and practice to formulate the Surface Brightness of Bodies and System of bodies

Comprehension questions:

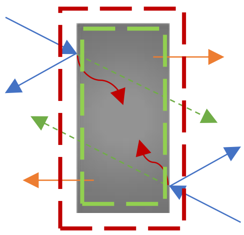
- ☐ How can surface brightness be interpreted physically?
- ☐ Which principles should be observed when setting up surface brightness?
- ☐ Why is infrared measurement of surface temperatures difficult? Which part of Surface Brightness carries this information?

Map 02: Surface Brightness

Learning goals:

- Training the ability to set up surface brightness's.

L07: Energy Balance



Learning goals:

- Understanding the concept of energy balances in radiative heat transfer
- Ability to set up energy balances around a body
- Understanding of internal and external energy balances

Comprehension questions:

- ☐ Which events lead to a temporal change of the thermal energy in the control volume?
- ☐ Which terms are considered additionally in the outer energy balance?
- ☐ How can inner and outer energy balance be transformed into each other?
- ☐ For which applications is an internal or external energy balance more useful?

Heat Transfer: Learning Path Radiation

Map 03: Energy Balances

Learning goals:

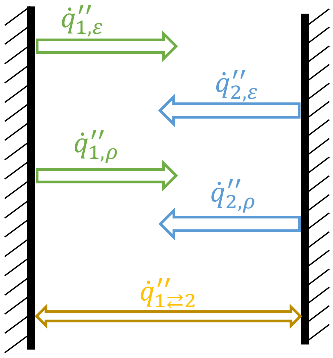
- Training the ability to set up energy balances and solve tasks with radiation

---

L08: Example: Radiation Transfer between two Gray Plates

Learning goals:

- Understanding the calculation of the radiation transfer between two surfaces by means of radiation tracking (Attention: not useful)
- Ability to describe the radiation exchange by means of surface brightness (Method of choice)



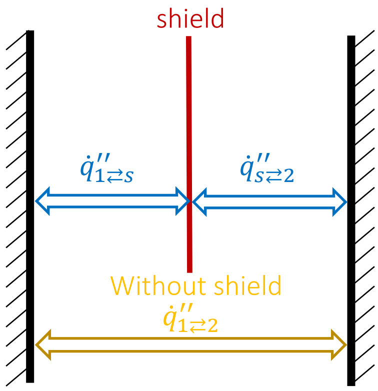
Comprehension questions:

- ☐ In which case is Radiation Tracking a reasonable method for calculation?
- ☐ Why is the use of surface brightness the more elegant method for calculating radiation transfer?

L09: Example: Protective Shield

Learning goals:

- How well can radiation be shielded and which properties make a good radiation protective shield (in the case of two parallel plates)?



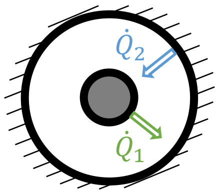
Comprehension questions:

- ☐ Why is the radiation exchange reduced, even in case of the shield being a black body?
- ☐ What happens when the three plates have identical radiation properties ($\varepsilon_1 = \varepsilon_2 = \varepsilon_s$)?

L10: Example: Radiation Transfer between two Self-enclosed Grey Bodies

Learning goals:

- Learn: Calculation of the radiation exchange for enclosed bodies to practice / to use: Approach for solving radiation tasks

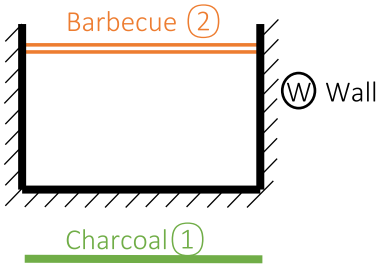


Comprehension questions:

- ☐ For self-enclosed grey bodies, which properties may contribute to increase radiative exchange?

- ☐ Which marginal cases exist and what they mean?

L11: Example: Three-body problem



Learning goals:

- ➢ Expansion of the balances from two-body to multi-body problems
- ➢ Learning the calculation scheme of radiation problems on the example of a three-body problem

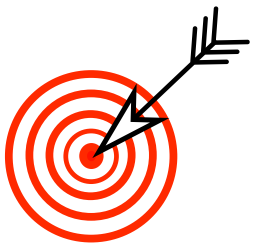
Comprehension questions:

- ☐ Why is calculation of radiation transfer much more complicated when a third object is added?
- ☐ If several bodies are involved in radiation exchange, can certain bodies be grouped together? In which case may bodies be grouped together?

L12: Summary: Procedure for Radiation Tasks?

Learning goals:

- ➢ Ability to solve radiation problems through a systematic approach



Comprehension questions:

- ☐ What are the most important points that need to be clarified before calculating radiation tasks?
