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Thermal insulation — Heat transfer by radiation — Vocabulary

Isolation thermique — Transfert de chaleur par rayonnement — Vocabulaire

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical Committee ISO/TC 163, *Thermal performance and energy use in the built environment*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 89, *Thermal performance of buildings and building components*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This second edition cancels and replaces the first edition (ISO 9288:1989), which has been technically revised.

The main changes are as follows:

— deleted the unit where two units existed (4.5, 4.6, 4.8, 4.9, 4.10, 5.3, 5.6, 6.2, 6.4);

— added the mean of d and d_∞ (7.15);

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document is intended to be used in conjunction with other vocabularies related to thermal insulation. These include:

— ISO 7345

— ISO 9229

— ISO 9251

— ISO 9346

Thermal insulation — Heat transfer by radiation — Vocabulary

1 Scope

This document defines physical quantities and other terms in the field of thermal insulation relating to heat transfer by radiation.

2 Normative references

There are no normative references in this document.

3 Terms and definitions (General terms)

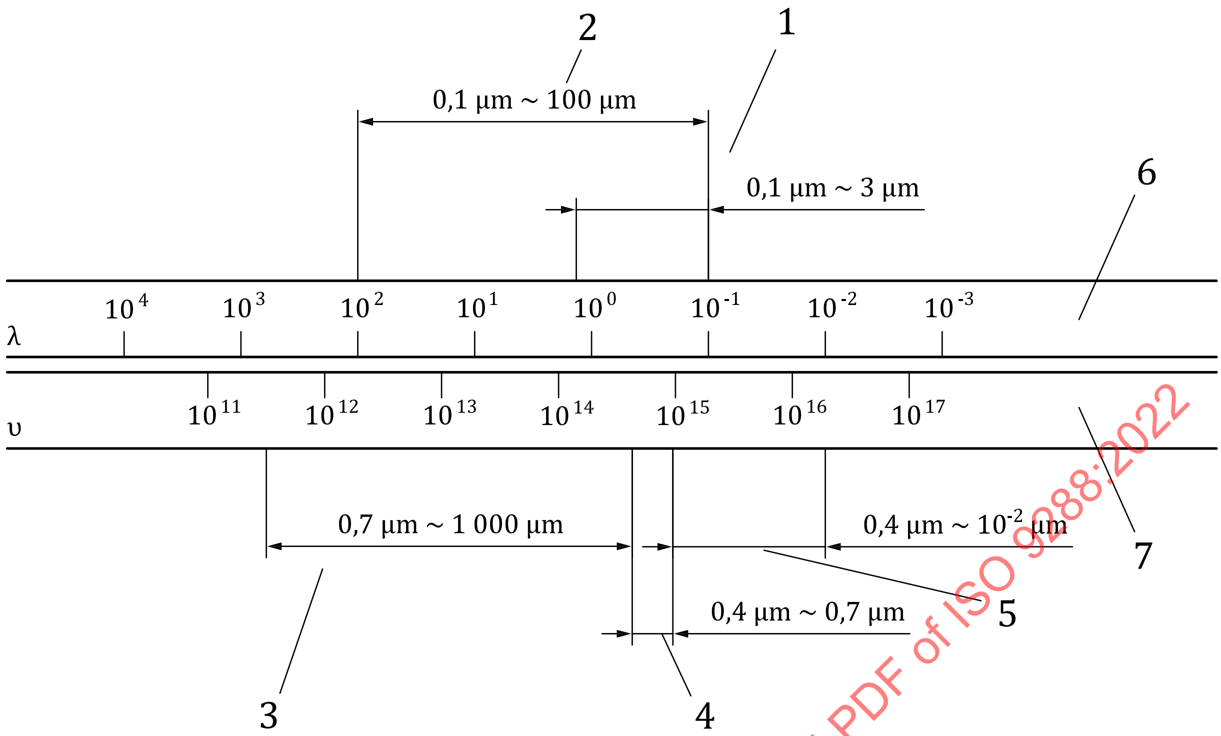
ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
thermal radiation
electromagnetic radiation emitted at the surface of an opaque body or inside an element of a semi-transparent volume

Note 1 to entry: The thermal radiation is governed by the temperature of the emitting body and its radiative characteristics. It is interesting from a thermal viewpoint when the wavelength range falls between 0, l μm and 100 μm (see Figure 1).



Key

1 solar radiation
2 thermal radiation
3 infrared
4 visible
5 ultraviolet
6 wavelength µm
7 frequency s^{-1}

Figure 1 — Electromagnetic wave spectrum

3.2
heat transfer by radiation
energy exchanged between bodies by means of electromagnetic waves

Note 1 to entry: These exchanges can occur when the bodies are separated from one another by vacuum or by a transparent or a semi-transparent medium. To evaluate these radiation heat exchanges it is necessary to know how opaque and semi-transparent bodies emit, absorb and transmit radiation as a function of their nature, relative position and temperature.

3.3
total radiation
entire spectrum of thermal radiation

3.4
spectral radiation
monochromatic radiation
spectral interval centred on the wavelength λ of thermal radiation, according to spectral distribution

3.5
hemispherical radiation
all directions of thermal radiation along which a surface element can emit or receive radiation, according to spatial distribution (directional)

3.6
directional radiation
thermal radiation whose directions of propagation are defined by a solid angle around the defined direction, according to spatial distribution

3.7
opaque medium
medium, which does not transmit any fraction of the incident radiation

Note 1 to entry: The absorption, *emission* (5.1) and reflection of radiation can be handled as surface phenomena

3.8
semi-transparent medium
medium, in which the incident radiation is progressively attenuated inside the material by absorption or scattering, or both

Note 1 to entry: The absorption, scattering and *emission* (5.1) of radiation are bulk (volume) phenomena.

Note 2 to entry: The radiative properties of an opaque or semi-transparent medium are generally a function of the spectral and directional distribution of incident radiation and of the temperature of the medium.

Note 3 to entry: Thermal insulating materials are generally semi-transparent media.

4 Terms related to surfaces either receiving, transferring or emitting a thermal radiation

4.1
radiant heat flow rate
radiant flux
Φ
heat flow rate emitted, transferred or received by a system in form of electromagnetic waves

Note 1 to entry: This is a total hemispherical quantity. See Table 1.

Note 2 to entry: Expressed in W.

4.2
total intensity
I_Ω
radiant heat flow rate (4.1) divided by the solid angle around the direction $\vec{\Delta}$:

$$I_\Omega = \frac{d\phi}{d\Omega}$$

Note 1 to entry: Expressed in W/sr.

4.3
total radiance
L_Ω
radiant heat flow rate (4.1) divided by the solid angle around the direction $\vec{\Delta}$ and the projected area normal to this direction:

$$L_\Omega = \frac{d^2\Phi}{d\Omega d(A\cos\theta)}$$

Note 1 to entry: Expressed in $\mathrm{W}/\left(\mathrm{m}^2 \cdot \mathrm{sr}\right)$.

4.4
spectral radiant heat flow rate
Φ_λ
radiant heat flow rate (4.1) divided by the spectral interval centred on the wavelength λ:

$$\phi_\lambda = \frac{d\phi}{d\lambda}$$

Note 1 to entry: Expressed in W/m.

4.5
spectral intensity
$I_{\Omega\lambda}$
total intensity (4.2) divided by the spectral interval centred on the wavelength λ:

$$I_{\Omega\lambda} = \frac{dI_\Omega}{d\lambda}$$

Note 1 to entry: Expressed in $\mathrm{W/(sr \cdot m)}$.

4.6
spectral radiance
$L_{\Omega\lambda}$
total radiance (4.3) divided by the spectral interval centred on the wavelength λ:

$$L_{\Omega\lambda} = \frac{dL_\Omega}{d\lambda}$$

Note 1 to entry: Expressed in $\mathrm{W/\left(m^3 \cdot sr\right)}$.

Note 2 to entry: Each spectral term A_λ is related to the corresponding total term A by a relation of the type

$$A_\lambda = \frac{dA}{d\lambda} \; or \; A = \int_0^\infty A_\lambda \, d\lambda$$

Note 3 to entry: Each directional term A_Ω is related to the corresponding hemispherical term A by a relation of the type

$$A_\Omega = \frac{dA}{d\Omega} \; or \; A = \int_{\Omega=4\pi} A_\Omega \, d\Omega$$

and

$$A_{\Omega\lambda} = \frac{d^2 A}{d\Omega d\lambda} \; or \; A = \int_{\Omega=4\pi} \int_0^\infty A_{\Omega\lambda} \, d\lambda d\Omega$$

Note 4 to entry: Total radiance and spectral radiance are oriented quantities (vectors) defined in each point of space where radiation exists (see Figure 3), moreover their values are independent of the particular surface used to define them. Sources which radiate with constant L_Ω (see 4.3) are called isotropic or diffuse.

Note 5 to entry: Intensities are oriented quantities too, but belong to a surface (see Figure 2).

Note 6 to entry: Radiant flows (total or spectral) are not oriented quantities and belong to a surface.

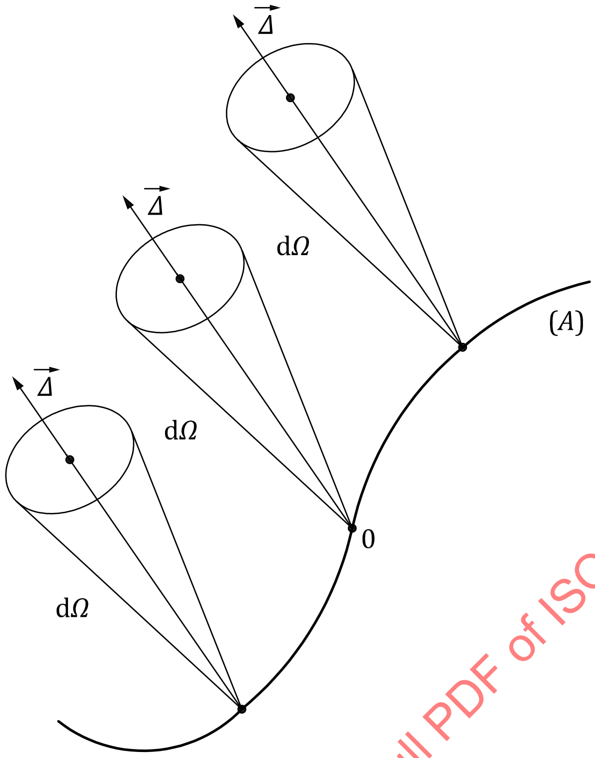


Figure 2 — Definition of the intensity

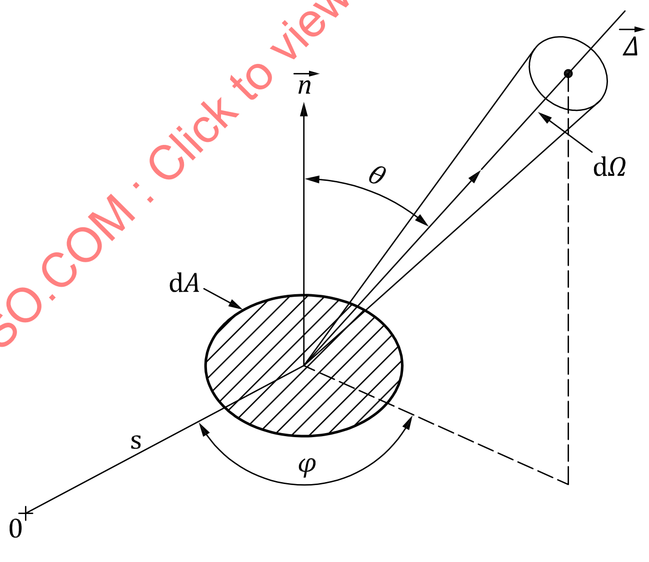


Figure 3 — Definition of the radiance

4.7
spectral radiant density of heat flow rate vector

$\overrightarrow{q_{r,\lambda}}$

$$\overrightarrow{q_{r,\lambda}} = \int_{\Omega=4\pi} L_{\Omega\lambda} \vec{\Delta} d\Omega$$

where

$L_{\Omega\lambda}$ is the *spectral radiance* (4.6);

$\vec{\Delta}$ is the solid angle around the direction.

Note 1 to entry: Expressed in W / m^3.

4.8
total radiant density of heat flow rate vector

$\overrightarrow{q_r}$

$$\overrightarrow{q_r} = \int_0^{\infty} \int_{\Omega=4\pi} L_{\Omega\lambda} \vec{\Delta} d\Omega d\lambda$$

where

$L_{\Omega\lambda}$ is the *spectral radiance* (4.6);

$\vec{\Delta}$ is the solid angle around the direction;

λ is the wavelength.

Note 1 to entry: Expressed in W/m^3.

4.9
spectral radiant density of heat flow rate

$q_{r,\lambda n}$

$$q_{r,\lambda n} = \vec{n} \cdot \overrightarrow{q_{r,\lambda}} = \int_{\Omega=4\pi} L_{\Omega\lambda} \vec{\Delta} \cdot \vec{n} d\Omega$$

where

$L_{\Omega\lambda}$ is the *spectral radiance* (4.6);

$\vec{\Delta}$ is the solid angle around the direction;

$\vec{n}$ is the heat flow rate in the direction.

Note 1 to entry: Expressed in W / m^3.

Note 2 to entry: Heat flow rate in the direction $\vec{n}$.

4.10
forward component of the spectral radiant density of heat flow rate

$q^+_{r,\lambda n}$

$$q^+_{r,\lambda n} = \vec{n} \cdot \overrightarrow{q_{r,\lambda}} = \int_{\Omega=2\pi} L_{\Omega\lambda} \vec{\Delta} \cdot \vec{n} d\Omega$$

where

$L_{\Omega\lambda}$ is the *spectral radiance* (4.6);

$\vec{\Delta}$ is the solid angle around the direction;

$\vec{n}$ is the heat flow rate in the direction.

Note 1 to entry: Expressed in W / m^3.

4.11
backward component of the spectral radiant density of heat flow rate
$q^{-}_{r,\lambda n}$

$$q^{-}_{r,\lambda n} = \vec{n} \cdot \overrightarrow{q_{r,\lambda}} = -\int_{\Omega=2\pi} L_{\Omega\lambda} \vec{\Delta} \cdot \vec{n} d\Omega$$

where

$L_{\Omega\lambda}$ is the *spectral radiance* (4.6);

$\vec{\Delta}$ is the solid angle around the direction;

$\vec{n}$ is the heat flow rate in the direction.

Note 1 to entry: Expressed in $\mathrm{W}/\left(\mathrm{m}^3\right)$.

Note 2 to entry: q_{r,λ_n} is expressed by the following:

$$q_{r,\lambda_n} = q^{+}_{r,\lambda_n} - q^{-}_{r,\lambda_n}$$

in combined unidirectional conduction and radiation heat transfer along a direction $\vec{n}$, gives

$$\overrightarrow{q_n} = \overrightarrow{q_{cd,n}} + \overrightarrow{q_{r,n}}$$

where

$\overrightarrow{q_n}$ is the density of heat flow rate as defined in ISO 7345;

$\overrightarrow{q_{cd,n}}$ is the density of heat flow rate by conduction;

$\overrightarrow{q_{r,n}}$ is the *total radiant density of heat flow rate vector* (4.8);

$\overrightarrow{q_n}$ can be determined experimentally with the guarded hot plate or heat flow meter method.

5 Terms related to surfaces emitting a thermal radiation

5.1
emission
process in which heat is transformed into electromagnetic waves

Note 1 to entry: Heat is from molecular agitation in, e.g. gases or atomic agitation in solids.

5.2
total exitance
M
radiant heat flow rate (4.1) emitted by a surface divided by the area of the emitting surface:

$$M = \frac{d\phi}{dA} = q_r^{+} \ or \ q_r^{-}$$

Note 1 to entry: M is the areal density of the heat flow rate in each point of an emitting surface. It is a total hemispherical quantity. See Table 1.

Note 2 to entry: Expressed in W/m^2.

5.3
spectral exitance
M_λ
total exitance (5.2) divided by the spectral interval, centred on the wavelength λ:

$$M_\lambda = \frac{dM}{d\lambda} = q^+_{r,\lambda} \ or \ q^-_{r,\lambda}$$

Note 1 to entry: Expressed in W/m^3 .

5.4
black body
full radiator
Planck radiator
BB
object that absorbs all the incident radiation for all wavelengths, directions and polarizations

Note 1 to entry: At a given temperature, for each wavelength it emits the maximum thermal energy [maximum *spectral exitance* (5.3)]. For this reason and because rigorous laws define its *emission* (5.1), the *emission of real bodies* (5.7) is compared with that of the black body.

Note 2 to entry: Terms related to black body bear a superscript notation (°).

5.5
black body total exitance
M^o
quantity defined by the formula:

$$M^o = \sigma T^4$$

where

σ is equal to 5,67 × 10⁻⁸ $W/(m^2 \cdot K^4)$;

T is the absolute temperature of the *black body* (5.4).

Note 1 to entry: Expressed in W/m^2.

Note 2 to entry: Expressed by the Stefan-Boltzmann law.

Note 3 to entry: Terms related to black body bear a superscript notation (°).

5.6
black body spectral exitance
M^o_λ
quantity defined by the formula:

$$M^o_\lambda = \frac{C_1 \lambda^{-5}}{exp(C_2 / \lambda \cdot T) - 1}$$

where

C_1 $= 2\pi h c_0^2 = 3{,}741 \times 10^{16}\ W/m^2$;

C_2 $= h c_0 / k = 0{,}014\ 388\ m \cdot K$;

h Planck constant;

k Boltzmann constant;

c_0 is the speed of electromagnetic waves in vacuum.

Note 1 to entry: A curve $M_\lambda^o = f(\lambda)$ with a maximum at λ_m can be drawn for each temperature. λ_m is a function of temperature, but the product $\lambda_m \cdot T$ is constant (Wien's "displacement law"):

$$\lambda_m \cdot T = 2{,}898 \times 10^{-3}\ \mathrm{m \cdot K}$$

Note 2 to entry: M^o and M_λ^o are hemispherical terms.

Note 3 to entry: The *emission* (5.1) of a black body is isotropic or diffuse, i.e. L^o and L_λ^o are independent of the direction (Lambert's law).

Note 4 to entry: The total and the *spectral radiance* (4.6) of the black body are expressed by:

$$L^o = \frac{M^o}{\pi}$$

$$L_\lambda^o = \frac{M_\lambda^o}{\pi}$$

Note 5 to entry: Expressed in $\mathrm{W/m^3}$.

Note 6 to entry: Expressed by Planck's law which relates M_λ^o to the wavelength λ and to the absolute temperature of the *black body* (5.4).

Note 7 to entry: Terms related to black body bear a superscript notation (°).

5.7
emission of real bodies
emission (5.1) properties of real materials compared with that of the *black body* (5.4) placed in the same conditions of temperature

Note 1 to entry: In general, these properties depend on the nature and surface aspect of the body and vary with wavelength, direction of emission and surface temperature.

5.8
total directional emissivity
ε_Ω
total radiance, L_Ω (4.3) emitted by the considered surface, divided by total radiance emitted by the *black body*, L_Ω^o (5.4) at the same temperature:

$$\varepsilon_\Omega = \frac{L_\Omega}{L_\Omega^o}$$

5.9
spectral directional emissivity
$\varepsilon_{\Omega\lambda}$
spectral radiance, $L_{\Omega\lambda}$ (4.6) of the considered surface divided by the spectral radiance emitted by the *black body*, $L_{\Omega\lambda}^o$ (5.4) at the same temperature:

$$\varepsilon_{\Omega\lambda} = \frac{L_{\Omega\lambda}}{L_{\Omega\lambda}^o}$$

5.10
total hemispherical emissivity
ε
total hemispherical exitance, M, of the considered surface divided by the total hemispherical exitance of the *black body*, M^o (5.4) at the same temperature:

$$\varepsilon = \frac{M}{M^o}$$

5.11
spectral hemispherical emissivity
ε_λ
spectral exitance, M_λ, (5.3) of the considered surface divided by the *spectral exitance of the black body*, M_λ^o (5.6) at the same temperature:

$$\varepsilon_\lambda = \frac{M_\lambda}{M_\lambda^o}$$

5.12
grey body
thermal radiator whose hemispherical or directional spectral emissivity is independent of wavelength

$$\varepsilon_\lambda = \varepsilon, \ \varepsilon_{\Omega\lambda} = \varepsilon_\Omega$$

5.13
isotropically emitting body
thermal radiator whose total or spectral emissivity is independent of the direction:

$$\varepsilon_\Omega = \varepsilon, \ \varepsilon_{\Omega\lambda} = \varepsilon_\lambda$$

5.14
isotropically emitting grey body
thermal radiator whose emissivity is independent of both wavelength and direction:

$$\varepsilon_\lambda = \varepsilon_{\Omega\lambda} = \varepsilon_\Omega = \varepsilon$$

Note 1 to entry: These emissivities can vary with temperature: $\varepsilon(T)$.

Note 2 to entry: The hypothesis of grey surfaces and isotropic *emission* (5.1), with an emissivity independent of wavelength and direction is generally accepted in computations. In this case, the different emissivities of a surface reduce to a single parameter, ε.

6 Terms related to opaque or semi-transparent surfaces receiving a thermal radiation

6.1
total irradiance
E
radiant heat flow rate (4.1) received by a surface divided by the area of this surface:

$$E = \frac{d\phi}{dA} = q_r^+ \ or \ q_r^-$$

Note 1 to entry: E is the areal density of the radiant heat flow rate in each point of a receiving surface. It is a total hemispherical quantity. See Table 1.

Note 2 to entry: Expressed in W/m^2.

Note 3 to entry: When radiant energy of a wavelength A strikes a material surface along a direction $\vec{\Delta}$ inside the solid angle Ω

— a part $\varrho_{\Omega\lambda}$ of the total incident radiation is reflected;

— a part $\alpha_{\Omega\lambda}$ is absorbed inside the material; and

— a part $\tau_{\Omega\lambda}$ may be transmitted.

The three terms $\alpha_{\Omega\lambda}$, $\varrho_{\Omega\lambda}$, $\tau_{\Omega\lambda}$ follow the relationship

$$\alpha_{\Omega\lambda} + \varrho_{\Omega\lambda} + \tau_{\Omega\lambda} = 1$$

Similar relations can be written for spectral, directional and total hemispherical terms. Spectral and total terms imply isotropic and incident radiation.

α = 1 for the black body;

τ = 0 for opaque bodies;

$\alpha = \alpha_\lambda$; $= \varrho_\lambda$; $\tau = \tau_\lambda$ for grey bodies;

$\alpha = \alpha_{\Omega\lambda}$; $\varrho = \varrho_{\Omega\lambda}$; $\tau = \tau_{\Omega\lambda}$ for isotropic or diffuse grey bodies.

Note 4 to entry: For a radiation of given direction and wavelength, all cases apply expression of the Kirchhoff law:

$$\alpha_{\Omega\lambda}(T) = \varepsilon_{\Omega\lambda}(T)$$

expression of the Kirchhoff law: for each wavelength and each direction of propagation of the radiation emitted or received by a surface, at a given temperature, the *spectral directional emissivity* (5.9) and absorbtivity are equal.

The Kirchhoff law holds also for monochromatic hemispherical terms:

$$\varepsilon_\lambda(T) = \alpha_\lambda(T)$$

but generally, this relation cannot be extended to the total radiation emitted and absorbed by a body. Thus, it is not possible to write $\varepsilon = \alpha$, except for grey and black bodies and/or in the case where the spectral distribution of the incident radiation is identical to the one of the *black body* (5.4) at the same temperature as the considered surface.

6.2
spectral irradiance

E_λ

irradiance divided by spectral interval centred on the wavelength λ:

$$E_\lambda = \frac{dE}{d\lambda} = q_{r,\lambda}^{+} \; or \; q_{r,\lambda}^{-}$$

Note 1 to entry: Expressed in W/m^3.

6.3
total radiosity

J

radiant heat flow rate (4.1) emitted and reflected by an opaque surface divided by the area of the surface:

$$J = \frac{d\phi}{dA} = q_r^{+} \; or \; q_r^{-}$$

Note 1 to entry: J is the areal density of radiant heat flow rate in each point of an opaque surface as a result of the *emission* (5.1) and the reflection of the surface.

Note 2 to entry: Expressed in $\mathrm{W/m^2}$.

6.4
spectral radiosity
J_λ
total radiosity (6.3) divided by the spectral interval centred on the wavelength λ:

$$J_\lambda = \frac{dJ}{d\lambda}$$

Note 1 to entry: Expressed in $\mathrm{W/m^3}$.

6.5
total absorptance
α
radiant heat flow rate (4.1) absorbed by a surface, ϕ_a, divided by the incident radiant heat flow rate Φ_i:

$$\alpha = \frac{\phi_a}{\Phi_i}$$

6.6
total reflectance
<ϱ>
radiant heat flow rate (4.1) reflected by a surface, Φ_r, divided by the incident radiant heat flow rate Φ_i:

$$\varrho = \frac{\Phi_r}{\Phi_i}$$

6.7
total reflectance
<τ>
radiant heat flow rate (4.1) transmitted by a surface, ϕ_t, divided by the incident radiant heat flow rate, Φ_i:

$$\tau = \frac{\phi_t}{\phi_i}$$

6.8
spectral absorptance
α_λ
spectral radiant heat flow rate (4.4) absorbed by a surface $\phi_{\lambda\alpha}$, divided by the incident spectral radiant heat flow rate, assuming that the incident radiation is isotropic:

$$\alpha_\lambda = \frac{\phi_{\lambda\alpha}}{\phi_{\lambda i}}$$

6.9
spectral reflectance
<$\varrho\lambda$>
spectral radiant heat flow rate (4.4) reflected by a surface $\phi_{\lambda r}$, divided by the incident spectral radiant heat flow rate, assuming that the incident radiation is isotropic:

$$\varrho_\lambda = \frac{\phi_{\lambda r}}{\phi_{\lambda i}}$$

6.10
spectral transmittance
<τ_λ>
spectral radiant heat flow rate (4.4) transmitted by a surface $\phi_{\lambda t}$, divided by the incident spectral radiant heat flow rate, assuming that the incident radiation is isotropic:

$$\tau_\lambda = \frac{\phi_{\lambda t}}{\phi_{\lambda i}}$$

6.11
spectral directional absorptance
$\alpha_{\Omega\lambda}$
spectral radiance (4.6) absorbed by a surface, $L_{\Omega\lambda a}$, divided by the spectral directional incident radiance, $L_{\Omega\lambda i}$:

$$\alpha_{\Omega\lambda} = \frac{L_{\Omega\lambda a}}{L_{\Omega\lambda i}}$$

6.12
spectral directional reflectance
$\varrho_{\Omega\lambda}$
spectral radiance (4.6) reflected by a surface in the direction Ω', $L_{\Omega'\lambda\mathrm{r}}$, divided by the spectral directional incident radiance, $L_{\Omega\lambda\mathrm{i}}$:

$$\varrho_{\Omega\lambda} = \frac{L_{\Omega'\lambda\mathrm{r}}}{L_{\Omega\lambda\mathrm{i}}}$$

Note 1 to entry: The reflection can be either diffuse or specular.

6.13
spectral directional transmittance
$\tau_{\Omega\lambda}$
spectral radiance (4.6) transmitted by a surface in the direction Ω', $L_{\Omega'\lambda t}$, divided by the spectral incident radiance, $L_{\Omega\lambda\mathrm{i}}$:

$$\tau_{\Omega\lambda} = \frac{L_{\Omega'\lambda\mathrm{t}}}{L_{\Omega\lambda\mathrm{i}}}$$

Note 1 to entry: The transmission can be either unidirectional or diffuse.

7 Terms related to a semi-transparent medium receiving a thermal radiation — Combined conduction and radiation heat transfer

7.1
spectral directional extinction coefficient
$\beta_{\Omega\lambda}$
spectral radiance (4.6) linear attenuation due to absorption along the direction $\vec{\Delta}$ and scattering along any other direction, divided by the incident spectral radiance:

$$\beta_{\Omega\lambda} = \frac{dL^{E}_{\Omega\lambda}}{ds} \times \frac{1}{L_{\Omega\lambda}}$$

Note 1 to entry: Expressed in m^{-1}.

7.2
spectral directional absorption coefficient
$x_{\Omega\lambda}$
spectral radiance (4.6) linear attenuation due to absorption along the direction $\vec{\Delta}$, divided by the incident spectral radiance:

$$x_{\Omega\lambda} = \frac{dL^{A}_{\Omega\lambda}}{ds} \times \frac{1}{L_{\Omega\lambda}}$$

Note 1 to entry: Expressed in m^{-1}.

7.3
spectral directional scattering coefficient
$\sigma_{\Omega\lambda}$
spectral radiance (4.6) linear attenuation along the direction $\vec{\Delta}$, due to scattering along any other direction, divided by the incident spectral radiance:

$$\sigma_{\Omega\lambda} = \frac{dL^{S}_{\Omega\lambda}}{ds} \times \frac{1}{L_{\Omega\lambda}}$$

Note 1 to entry: The terms $\beta_{\Omega\lambda}$, $x_{\Omega\lambda}$ and $\sigma_{\Omega\lambda}$ follow the relationship

$$\beta_{\Omega\lambda} = x_{\Omega\lambda} + \sigma_{\Omega\lambda}$$

Note 2 to entry: Expressed in m^{-1}.

7.4
mass spectral directional extinction coefficient
$\beta'_{\Omega\lambda}$
spectral directional extinction coefficient (7.1) divided by the density of the semi-transparent medium:

$$\beta'_{\Omega\lambda} = \frac{\beta_{\Omega\lambda}}{\varrho}$$

Note 1 to entry: Expressed in m^2/kg.

7.5
mass spectral directional absorption coefficient
$x'_{\Omega\lambda}$
spectral directional absorption coefficient (7.2) divided by the density of the semi-transparent medium:

$$x'_{\Omega\lambda} = \frac{x_{\Omega\lambda}}{\varrho}$$

Note 1 to entry: Expressed in m^2/kg.

7.6
mass spectral directional scattering coefficient
$\sigma'_{\Omega\lambda}$
spectral directional scattering coefficient (7.3) divided by the density of the semi-transparent medium:

$$\sigma'_{\Omega\lambda} = \frac{\sigma_{\Omega\lambda}}{\varrho}$$

Note 1 to entry: If the semi-transparent medium is an isotropic material it gives

$$\beta_{\Omega\lambda} = \beta_\lambda,\ x_{\Omega\lambda} = x_\lambda,\ \sigma_{\Omega\lambda} = \sigma_\lambda$$

If it is an isotropic and grey material it gives

$$\beta_{\Omega\lambda} = \beta,\ x_{\Omega\lambda} = x,\ \sigma_{\Omega\lambda} = \sigma$$

Note 2 to entry: Expressed in m^2/kg.

7.7
spectral directional optical thickness
$\tau_{\Omega\lambda}$
value defined by

$$\tau_{\Omega\lambda}(d) = \int_0^d \beta_{\Omega\lambda}(s)ds$$

Note 1 to entry: A layer of thickness d, is a measure of the ability of a given path length of semi-transparent material to attenuate thermal radiation of wavelength λ and for homogeneous isotropic and isothermal layers $\beta_{\Omega\lambda}(d)$ = constant, and $\tau_\lambda = \beta_\lambda \cdot d$.

7.8
phase function
P_λ
mathematical function describing the space distribution of the scattered radiation:

$$\frac{P_\lambda\left(\vec{\Delta}' \to \vec{\Delta}\right)d\Omega}{4\pi}$$

Note 1 to entry: It represents the probability for an incident radiation inside the solid angle $d\Omega'$ around the direction $\vec{\Delta}'$ to be scattered in the unit solid angle around direction $\vec{\Delta}$.

Note 2 to entry: It characterizes an anisotropic scattering material if the scattered radiation is isotropic $P_\lambda\left(\vec{\Delta}' \to \vec{\Delta}\right) = 1$.

7.9
spectral directional albedo
$\omega_{\Omega\lambda}$
spectral directional scattering coefficient (7.3) divided by the *spectral directional extinction coefficient* (7.1):

$$\omega_{\Omega\lambda} = \frac{\sigma_{\Omega\lambda}}{\beta_{\Omega\lambda}}$$

Note 1 to entry: For isotropic media, $\omega_{\Omega\lambda}$ is independent of the direction and the spectral term ω_λ may replace it. For absorbing, non-scattering media $(\sigma_\lambda = 0)$, $\omega_\lambda = 0$, and for non-absorbing scattering media $(x_\lambda = 0)$, $\omega_\lambda = 1$.

7.10
semi-transparent plane layer
semi-transparent layer of thickness d, limited by two infinite, plane and parallel boundaries of given thermal and optical characteristics

7.11
equation of radiative transfer
mathematical relation describing the variation along a path of the *spectral radiance* (4.6) in an absorbing, emitting and scattering medium

Note 1 to entry: The solution of this equation depends on the radiative properties of the medium, e.g. spectral extinction coefficient, spectral albedo and spectral phase function (7.8), and on the thermal and optical boundary conditions.

7.12
Rosseland diffusion approximation
approximation of the *equation of radiative transfer* (7.11) considering the medium optically thick and without taking into consideration the boundary conditions

7.13
Schuster-Schwartzschild two-flux approximation
approximation of the *equation of radiative transfer* (7.11) for one dimensional planar geometry based on the assumption that the *spectral radiances* (4.6) with positive components of direction can be integrated in a single term, $q_{r\lambda}^{+}$, while spectral radiances with negative components can be integrated in a single term, $q_{r\lambda}^{-}$

Note 1 to entry: One dimensional planar geometry is a *semi-transparent plane layer* (7.10).

7.14
radiative thermal conductivity
λ_r
quantity defined by the following relation:

$$\overrightarrow{q_r} = -\lambda_r \, grad \; T$$

rewritten in the following way for a plane layer:

$$q_r = -\lambda_r \frac{\partial T}{\partial n}$$

where n is the normal to the layer

Note 1 to entry: These relations are the consequence of *Rosseland approximation* (7.12) and their advantage is that they provide simple relations to express the total radiative density of heat flow rate, similar to Fourier's law for pure conductive heat transfer.

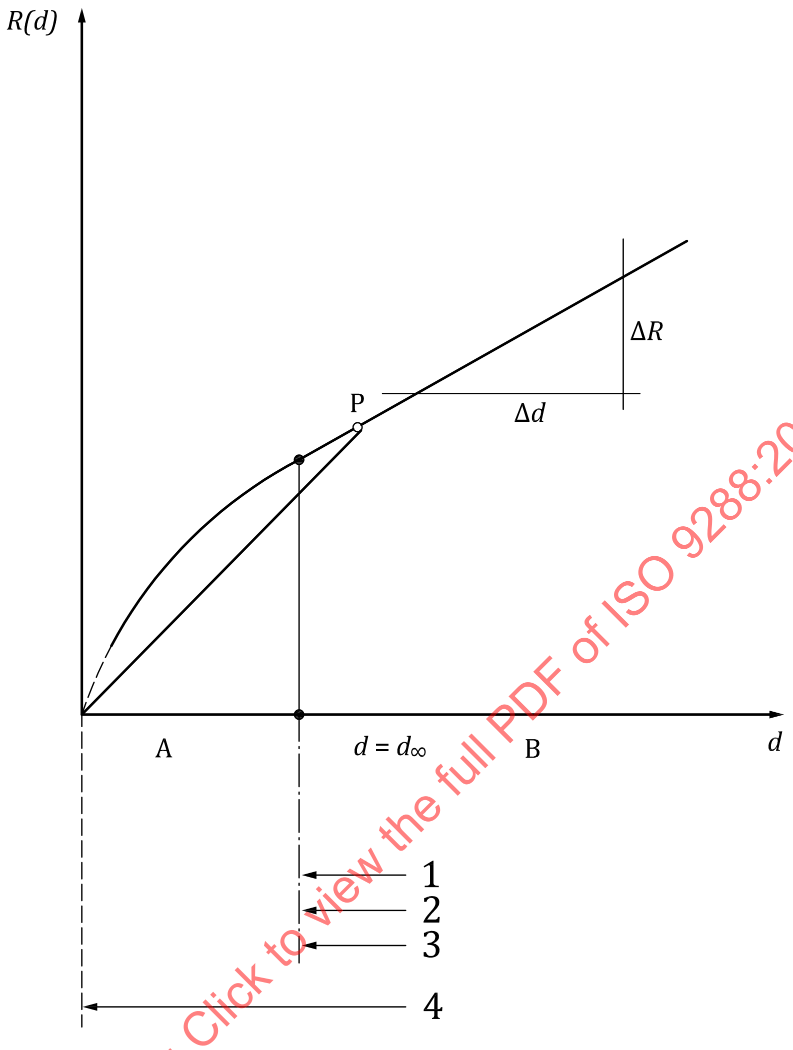
Note 2 to entry: Expressed in $\mathrm{W}/(\mathrm{m}\cdot\mathrm{K})$.

7.15
transfer factor
g
material property of a semi-transparent insulating product in relation with the combined conduction and radiation heat transfer, which depends on experimental conditions, expressed by:

$$g = \frac{qd}{\Delta T} = \frac{d}{R}$$

Note 1 to entry: It can be derived from the measurement of q, d and ΔT in a guarded hot plate; it is a material property only when $d \gg d_\infty$ (see Figure 4), where d is thickness and d_∞ is the thickness when $\Delta d / \Delta R$ become constant.

Note 2 to entry: Expressed in $\mathrm{W}/(\mathrm{m}\cdot\mathrm{K})$.



Key

1 radiativity, λ_r

2 gaseous and solid conductivity, λ_{cd}

3 thermal transmissivity, $\lambda_t = \lambda_{cd} + \lambda_r$

4 transfer factor, g

Zone A $(d < d_\infty)$: The ratio $\Delta d / \Delta R$ is not constant, λ_t cannot be measured; the transfer factor, g, is not an intrinsic material property as it depends on experimental conditions.

Zone B$(d \geq d_\infty)$: The ratio $\Delta d / \Delta R$ is constant; the thermal transmissivity, λ_t, that is an intrinsic material property independent of the experimental conditions, can now be measured. In this case we can also define λ_r and λ_{cd} as material properties and put $\lambda_t = \lambda_{cd} + \lambda_r$. Nevertheless, $g = d / R$ is not yet independent of the thickness d; see point P. $g = \lambda_t$ will take place only for $d \gg d_\infty$.

Figure 4 — Thermal resistance versus thickness