LIST OF SYMBOLS

The following is a list of symbols used frequently in this book. A number of symbols have been used for several different purposes. Alas, the Roman alphabet has only 26 lowercase and another 26 uppercase letters, and the Greek alphabet provides 34 more different ones, for a total of 86, which is, unfortunately, not nearly enough. Hopefully, the context will always make it clear which meaning of the symbols is to be used. I have used what I hope is a simple and uncluttered set of variable names. This usage, of course, comes at a price. For example, the subscript "λ" is often dropped (meaning "at a given wavelength," or "per unit wavelength"), assuming that the reader recognizes the variable as a spectral quantity from the context. Whenever applicable, units have been attached to the variables in the following table. Variables without indicated units have multiple sets of units. For example, the units for total band absorptance A depend on the spectral variable used (λ, η, or ν), and on the absorption coefficient (linear, density- or pressure-based), for a total of nine different possibilities.

a	semimajor axis of polarization ellipse, [N/C]
a	plane-polarized component of electric field, [N/C]
a	particle radius, [m]
a	weight function for full-spectrum k-distribution methods, [−]
a_k	weight factors for sum-of-gray-gases, [−]
a_n, b_n	Mie scattering coefficients, [−]
A	total band absorptance (or effective band width)
A^*	nondimensional band absorptance = A/ω, [−]
A, A_n	slab absorptivity (of n parallel sheets), [−]
A, A_p	area, projected area, [m^2]
A_m	scattering phase function coefficients, [−]
A_{ij}, B_{ij}	Einstein coefficients
b	self-broadening coefficient, [−]
b	semiminor axis of polarization ellipse, [N/C]
B	rotational constant
Bo	convection-to-radiation parameter (Boltzmann number), [−]
c, c_0	speed of light, (in vacuum), [m/s]
c	specific heat, [J/kg K]
C_1, C_2, C_3	constants for Planck function and Wien's displacement law
C_1, C_2, C_3	wide band parameters for outdated model
d	line spacing
d^n_{ij}, D^n_{ij}	Wigner-D functions, [−]
D	diameter, [m]
D, D^*	detectivity (normalized), [1/W] ([cm Hz$^{1/2}$/W])
D_f	mass fractal dimension, [−]
$\hat{\mathbf{e}}$	unit vector into local coordinate direction, [−]
E, E_b	emissive power, blackbody emissive power
E	molecular energy level, [J]
$\mathbf{E}$	electric field vector, [N/C]
$E(m)$	refractive index function, [−]
E_n	exponential integral of order n, [−]
f	k-distribution, [cm]
f	probability density function

f_v, f_s, f_l	volume, solid, liquid fractions, [−]
$f(n\lambda T)$	fractional blackbody emissive power, [−]
F	objective function
F	wide band k-distribution, [cm]
F_{i-j}	(diffuse) view factor, [−]
F^s_{i-j}	specular view factor, [−]
$\mathscr{F}_{i\to j}$	radiation exchange factor, [−]
g_k	degeneracy, [−]
g	nondimensional incident radiation, [−]
g	cumulative k-distribution, [−]
$\overline{g_i s_j}, \overline{g_i g_k}$	direct exchange areas in zonal method, [cm^2]
$\overline{\mathbf{gs}}, \overline{\mathbf{gg}}$	direct exchange area matrix, [cm^2]
G	incident radiation = direction-integrated intensity
$\overline{G_i S_j}, \overline{G_i G_k}$	total exchange areas in zonal method, [cm^2]
$\mathbf{G}$	dyadic Green's function
h	Planck's constant = 6.6261×10^{-34} J s
h	convective heat transfer coefficient, [W/m^2 K]
H	irradiation onto a surface
H	Heaviside's unit step function, [−]
H	nondimensional heat transfer coefficient, [−]
$\mathscr{H}$	nondimensional irradiation onto a surface, [−]
$\mathbf{H}$	magnetic field vector, [C/m s]
i	nondimensional polarized intensity, [−]
$\hat{\mathbf{i}}$	unit vector into the x-direction, [−]
I	intensity of radiation
I	first Stokes' parameter for polarization, [N^2/C^2]
I	moment of inertia, [kg cm^2]
I_b	blackbody intensity (Planck function)
I_l, I_l^m	position-dependent intensity functions
I_0, I_1	modified Bessel functions, [−]
$\Im$	imaginary part of complex number
j	rotational quantum number, [−]
$\hat{\mathbf{j}}$	unit vector into the y-direction, [−]
J	radiosity, [W/m^2]
$\mathscr{J}$	nondimensional radiosity, [−]
k	thermal conductivity, [W/m K]
k	Boltzmann's constant = 1.3807×10^{-23} J/K
k	absorptive index in complex index of refraction, [−]
k	absorption coefficient variable, [cm^{-1}]
k_f	fractal prefactor, [−]
$\hat{\mathbf{k}}$	unit vector into the z-direction, [−]
K	kernel function
K	luminous efficacy, [lm/W]
l, m, n	direction cosines with x-, y-, z-axis, [−]
L	length, [m]
L	latent heat of fusion, [J/kg]
L	luminance
L_e	mean beam length, [m]
L_0, L_m	geometric, or average mean beam length, [m]
$\mathscr{L}$	Laplace transform, or differential operator
m	mass, [kg]

m	complex index of refraction, [−]
$\dot{m}$	mass flow rate, [kg/s]
$\mathscr{M}$	molecular weight, [kg/kmol]
n	self-broadening exponent, [−]
n	refractive index, [−]
n	number distribution function for particles, [cm^{-4}]
$\hat{\mathbf{n}}$	unit surface normal (pointing away from surface into the medium), [−]
N	conduction-to-radiation parameter (Stark number), [−]
N_c	conduction-to-radiation parameter, [−]
N_T	number of particles per unit volume, [m^{-3}]
Nu	Nusselt number, [−]
$\mathscr{O}\{\}$	order of magnitude, [−]
p	pressure, [bar]; radiation pressure, [N/m^2]
$\mathbf{p}$	parameter vector
P	probability function, [−]
P_l, P_l^m	(associated) Legendre polynomials, [−]
Pr	Prandtl number, [−]
q, $\mathbf{q}$	heat flux, heat flux vector, [W/m^2]
q_R	radiative flux, [W/m^2]
q_{lum}	luminous flux, [lm/m^2 = lx]
Q	heat rate, [W]
Q	second Stokes' parameter for polarization, [N^2/C^2]
$\dot{Q}'''$	heat production per unit volume, [W/m^3]
r	radial coordinate, [m]
r	reflection coefficient, [−]
$\mathbf{r}$	position vector, [m]
R	radius, [m]
R_u	universal gas constant = 8.3145 J/mol K
R	random number, [−]
R	radiative resistance, [cm^{-2}]
R, R_n	slab reflectivity (of n parallel sheets), [−]
$\Re$	real part of complex number
Re	Reynolds number, [−]
s	geometric path length, [m]
$\hat{\mathbf{s}}$	unit vector into a given direction, [−]
$\overline{s_i s_j}, \overline{s_i g_k}$	direct exchange areas in zonal method, [cm^2]
$\overline{\mathbf{ss}}, \overline{\mathbf{sg}}$	direct exchange area matrix, [cm^2]
S	distance between two zones, or between points on enclosure surface, [m]
S	line-integrated absorption coefficient = line strength
S	radiative source function
$\mathbf{S}$	Poynting vector, [W/m^2]
St	Stanton number, [−]
Ste	Stefan number, [−]
$\overline{S_i S_j}, \overline{S_i G_k}$	total exchange areas in zonal method, [cm^2]
$\overline{\mathbf{SS}}, \overline{\mathbf{SG}}$	total exchange area matrix, [cm^2]
t	time, [s]
t	transmission coefficient, [−]
t	fin thickness, [m]
$\hat{\mathbf{t}}$	unit vector in tangential direction, [−]
T	temperature, [K]
T, T_n	slab transmissivity (of n parallel sheets), [−]

u	internal energy, [J/kg]
u	radiation energy density
u	velocity, [m/s]
u	scaling function for absorption coefficient, [−]
u_k	nondimensional transition wavenumber, [−]
U	third Stokes' parameter for polarization, [N^2/C^2]
v	vibrational quantum number, [−]
v	velocity, [m/s]
$\mathbf{v}$	velocity vector, [m/s]
V	volume, [m^3]
V	fourth Stokes' parameter for polarization, [N^2/C^2]
$\mathbf{w}$	wave vector, [cm^{-1}]
w_i	quadrature weights, [−]
W	equivalent line width
$\mathbf{W}$	weighting matrix, [−]
x, y, z	Cartesian coordinates, [m]
x	particle size parameter, [−]
x	line strength parameter, [−]
x	mole fraction, [−]
X	optical path length
X	interface location, [m]
$\mathbf{X}$	sensitivity matrix
Y	mass fraction, [−]
Y_l^m	spherical harmonics, [−]
z	nondimensional spectral variable, [−]
α	absorptance or absorptivity, [−]
α	band-integrated absorption coefficient = band strength parameter
α	opening angle, [rad]
α	thermal diffusivity, [m^2/s]
α, β, γ	Euler rotation angles, [−]
β	extinction coefficient
β	line overlap parameter, [−]
β^*	line overlap parameter for dilute gas, [−]
γ	complex permittivity, [$C^2/N\,m^2$]
γ	azimuthal rotation angle for polarization ellipse, [rad]
γ	oscillation damping factor, [Hz]
γ	line half-width
γ_E	Euler's constant = 0.57221...
δ	Dirac-delta function, [−]
δ	polarization phase angle, [rad]
δ_{ij}	Kronecker's delta, [−]
δ_k	vibrational transition quantum step = Δv, [−]
Δ_{ij}^n	rotation matrix, [−]
ϵ	emittance or emissivity, [−]
ϵ	electrical permittivity, [$C^2/N\,m^2$]
ε	complex dielectric function, or relative permittivity, = $\varepsilon' - i\varepsilon''$, [−]
η	wavenumber, [cm^{-1}]
η	direction cosine, [−]
η	nondimensional (similarity) coordinate, [−]
η_{lum}	luminous efficiency, [−]
θ	polar angle, [rad]

θ	nondimensional temperature, [−]
Θ	scattering angle, [rad]
Θ	Planck oscillator, [J]
κ	absorption coefficient
λ	wavelength, [μm]
λ_m	overlap parameter, [cm^{-1}]
λ	regularization parameter, [−]
μ	dynamic viscosity, [kg/m s]
μ	magnetic permeability, [$\text{N s}^2/\text{C}^2$]
μ	direction cosine (of polar angle), $\cos\theta$, [−]
ν	frequency, [Hz]
ν	kinematic viscosity, [m^2/s]
ξ	direction cosine, [−]
ξ	nondimensional coordinate, [−]
ρ	reflectance or reflectivity, [−]
ρ	density, [kg/m^3]
ρ_f	charge density, [C/m^3]
σ	Stefan–Boltzmann constant = $5.670 \times 10^{-8}\ \text{W/m}^2\,\text{K}^4$
σ_s	scattering coefficient
$\sigma_e, \sigma_{\text{dc}}$	electrical conductivity, dc-value, [$\text{C}^2/\text{N m}^2\,\text{s} = 1/\Omega\,\text{m}$]
σ_h	root-mean-square roughness, [cm]
σ_l	correlation length, [cm]
τ	transmittance or transmissivity, [−]
τ	optical coordinate, optical thickness, [−]
ϕ	phase angle, [rad]
ϕ	normalized line shape function
$\boldsymbol{\phi}$	composition variable vector $(T, p, \mathbf{x})$
Φ	scattering phase function, [sr^{-1}]
Φ	nondimensional medium emissive power function
Φ	temperature function for line overlap β, [−]
Φ	dissipation function, [J/kg m^2]
ψ	azimuthal angle, [rad]
ψ	stream function, [m^2/s]
Ψ	temperature function for band strength α, [−]
Ψ	nondimensional heat flux
ω	single scattering albedo, [−]
ω	angular frequency, [rad/s]
ω	relaxation parameter, [−]
Ω	solid angle, [sr]

Subscripts

0	reference value, or in vacuum, or at length = 0
1, 2	in medium, or at location, "1" or "2"
∞	far from surface
a	absorbing, or apparent
av	average
b	blackbody value
B	band integrated value
c	at band center, or at cylinder, or critical value, or denoting a complex quantity, or cold
C	collision
D	Doppler, or based on diameter

e	effective value, or at equilibrium
f	fluid
g	gas, or at a given cumulative k-distribution value
h	hot
i	incoming, or dummy counter
j	at a rotational state, or dummy counter
k	at a given value of the absorption coefficient variable
L	at length = L
m	modified Planck value, or medium value, or mean (bulk) value
n	in normal direction
o	outgoing, or from outside
p	related to pressure, or polarizing value
p	plasma
P	Planck-mean
r	reflected component
ref	reference value
R	Rosseland-mean, or radiation, or at $r = R$
s	along path s, or at surface, or at sphere, or at source, or solid
S	Stark
sol	solar
t	transmitted component
u	upper limit
v	at a vibrational state, or at constant volume
w	wall value
W	value integrated over spectral windows
x, y, z, r	in a given direction
θ, ψ	in a given direction
η	at a given wavenumber, or per unit wavenumber
λ	at a given wavelength, or per unit wavelength
ν	at a given frequency, or per unit frequency
$\parallel$	polarization component, or situated in plane of incidence
$\perp$	polarization component, or situated in plane perpendicular to plane of incidence

Superscripts

$'$ $''$	real and imaginary parts of complex number, or directional values, or dummy variables
$\frown$	hemispherical value
$*$	complex conjugate, or obtained by P_1-approximation
$+, -$	into "positive" and "negative" directions
d	diffuse
s	specular
$\bar{}$	average value
$\tilde{}$	complex number, or scaled value (for nonisothermal path), or Favre average
$\hat{}$	unit vector