SYMBOLS

A	surface area
$A_{n\rightarrow m}$	Einstein Coefficient of spontaneous emission
$\bar{A}_b(s)$	effective bandwidth
a	mean absorption coefficient; gray-medium absorption coefficient
a_λ, a_η	absorption coefficient
a_η^*	dimensionless absorption coefficient
B	total number of V-R bands for a given gas or gas mixture
$B_{m\rightarrow n}$	Einstein coefficient of absorption
$B_{n\rightarrow m}$	Einstein coefficient of stimulated emission
$B_k\left(\mathbf{u}_k\right)$	quantity defined by Eqs. (19.8) - (19.9)
$B_{k-j}(n)$	quantity defined by Eq. (22.33)
b	integer indicating to which V-R bands reference is being made
C	constant; also, symbol for a curve in the plane
C_s	scattering cross section of a particle
C_a	absorption cross section of a particle
c	speed of electromagnetic wave
c_o	speed of electromagnetic waves in free space
c_f	factor correcting the geometric mean beam length
D	diameter, molecular diameter, plane layer thickness
$\hat{\mathbf{d}}$	unit vector indicating a particular direction in space
d	number of diffuse surfaces in a specular enclosure
$\mathbf{E}$	electric field intensity
E_x, E_y, E_z	components of $\mathbf{E}$
E_0	amplitude of a sinusoidal electric field
E	energy of a photon
E_{nm}	$e_n - e_m$
$E_\perp, E_\parallel$	components of $\mathbf{E}$ perpendicular and parallel to plane of incidence
E_g	semiconductor's energy gap
E_l	photon energy associated with the l^{th} line of a band structure
$E_n(x)$	exponential integral function
e	energy of a fundamental particle
e_m	energy of the m^{th} discrete energy level available to a particle
e_i	energy level associated with the i^{th} quantum state of a system
e_λ	emissive power
$e_{\lambda b}$ $e_{\eta b}$	blackbody emissive power
e	total emissive power

e	total blackbody emissive power
$e_{\lambda bk}$, $e_{\eta bk}$	$e_{\lambda b}$, $e_{\eta b}$ evaluated at temperature T_k
$\hat{\mathbf{e}}$	unit vector along a line joining two points on an enclosure surface
$\mathbf{e}_{\lambda b}$	blackbody vector; its elements are the set of $e_{\lambda bk}$'s
$F_{d\text{i}-j}$	point form factor from elemental area di to surface j
F_{i-j}	form factor from surface i to surface j
$F_{0-x}(x)$	(universal) fractional blackbody energy function
$\mathbf{F}$	form factor matrix with elements F_{i-j}
F^s_{k-j}	specular form factor from surface k to surface j
$\mathbf{F}^s$	specular form factor matrix with elements F^s_{k-j}
$\Im_{\lambda k-j}$	exchange factor from surface k to surface j
$\overline{\Im}_{k-j}(T)$	total exchange factor from k to j, for temperature T
$\overrightarrow{\Im}_{\lambda}$	exchange factor matrix
$\Im^s_{k-j}$	specular enclosure exchange factor from k to j
$\overrightarrow{\Im}^s$	specular enclosure exchange factor matrix
$\overrightarrow{\Im}(a_\eta)$	gaseous exchange factor matrix
$f_{0-\lambda}(T)$	fraction of $e_{\lambda b}$ at temperature T with wavelength $\leq \lambda$
$f_{\lambda_1-\lambda_2}(T)$	fraction of $e_{\lambda b}$ at temperature T with wavelength between λ_1 and λ_2
f_v	volume fraction of a sooty gas occupied by soot particles
$G_{d1-j}(x)$	gaseous point form factor (function) from area di to surface j
$G_{k-j}(x)$	gaseous form factor (function) from surface k to surface j
G_{sc}	solar constant
$\mathbf{G}(x)$	matrix of gaseous form factor functions
$\mathbf{H}$	magnetic field intensity
H_x, H_y, H_z	components of $\mathbf{H}$
H_0	amplitude of a sinusoidal variation in $\mathbf{H}$
H_n, H_k	hemispherical solid angle bisected by $\hat{\mathbf{n}}$ or $\hat{\mathbf{k}}$
h_P	Planck's constant
h_c	convective heat transfer coefficient
h_{rk-j}	radiative heat transfer coefficient between surfaces k and j
$\mathbf{I}$	identity matrix
I	number of image surfaces in a specular enclosure
i	quantum state number
i'_λ, i'_η	intensity
$i'_{\lambda b}$, $i'_{\eta b}$	blackbody intensity
$i'_{\lambda bn}$	blackbody intensity inside medium of index of refraction n
i', i'_b	total intensity, total blackbody intensity
$\widehat{\mathbf{i}}$	unit vector along x-axis
$J(u,v)$	surface factor for a parametric surface, $= \lvert\mathbf{J}(u,v)\rvert$
$\mathbf{J}(u,v)$	surface normal for a parametric surface

j	integer representing a particular enclosure surface
$\widehat{\mathbf{j}}$	unit vector along y-axis
$K_{x\lambda}$	extinction coefficient
$K(...)$	kernel of an integral equation
K, K_D	optical depths for gray medium: $K = ax$, $K_D = aD$
k_B	Boltzmann constant
$\hat{\mathbf{k}}$	unit vector along the z-axis
k	thermal conductivity of medium
k	integer representing a particular enclosure surface
$k(...)$	kernel of a single-variable integral equation
L	distance or dimension
l	integer representing a particular line in a band
M	molecular mass
N	number of particles per unit volume
N	total number of surfaces in an enclosure
N_p	number of scattering particles per unit volume
N_c	number of FCM surfaces in an enclosure
$\mathbf{N}$	normal to a surface or curve
N_f	number of terms in a truncated Fourier series
N_1, N_2	conduction/radiation parameters
n	index of refraction
$n_{P,E}$ ($n'_{P,E}$)	spectral (directional) photon density
$\hat{\mathbf{n}}$	unit vector normal to a surface
n_r	rotational quantum number
n_v	vibrational quantum number
$P(e)$	probability that system is in quantum state of energy e
P	pressure
$\mathbf{P}$	vector of power carried by an electromagnetic wave
P_x, P_y, P_z	components of $\mathbf{P}$
P_E	equivalent-broadening pressure
P_A	partial pressure of active component of a gas mixture
P_0	reference pressure equal to one atmosphere
$P_{\mathrm{H_2O}}$	partial pressure of H_2O
$P_{\mathrm{CO_2}}$	partial pressure of CO_2
$Q_{r\lambda}$	radiant heat flow over a finite surface
Q_k	total rate at which radiative heat leaves surface k
Q_g	total rate at which radiative heat leaves the gas
$Q_{\lambda k}$, $Q_{\eta k}$	spectral rate at which radiative heat leaves surface k
$q_{r\lambda}$, q_{rE}, $q_{r\eta}$	radiant heat flux
$q_{r\lambda,bn}$	radiant heat flux in a medium of index of refraction n, at photonic equilibrium

q_r	total radiant heat flux
$q_{r\lambda,\omega}$	partial radiant heat flux
$\hat{q}_{r\lambda}$	net radiant heat flux
$\bar{q}_{r\lambda k}$	average radiant heat flux over surface k
$\mathbf{q}_r$	vector of radiant heat fluxes
$\hat{q}_{ri}$, $\hat{q}_{rj}$, $\hat{q}_{rk}$	components of $\mathbf{q}$
q_r'''	rate per unit volume at which radiant energy leaves medium
$q_{s\lambda}$, $q_{s\eta}$	(spectral) surface heat flux
q_s	surface heat flux
$q_{\lambda ok}$, $q_{\eta ok}$	outgoing radiant heat flux at surface k
$\bar{q}_{\lambda ok}$, $\bar{q}_{\eta ok}$	average outgoing radiant heat flux at surface k
q_{ok}	total outgoing radiant heat flux at surface k
$\bar{q}_{ok}$	average total outgoing radiant heat flux over surface k
$\mathbf{q}_{\lambda o}$, $\mathbf{q}_{\eta o}$	vector of average outgoing radiant heat fluxes
$\mathbf{q}_o$	vector of total average outgoing radiant heat fluxes
$\mathbf{q}_\lambda$, $\mathbf{q}_\eta$	spectral heat flow vector
$\mathbf{q}$	total heat flow vector
$R_{sp,n\to m}$	rate of spontaneous emissions $n \to m$, per unit volume
$R_{st,n\to m}$	rate of stimulated emissions $n \to m$, per unit volume
$R_{ab,m\to n}$	rate of absorption transitions $m \to n$, per unit volume
R	radius
$R'_{sp,n\to m}$	directional rate of spontaneous emission transitions $n \to m$, per unit volume
$R'_{st,n\to m}$	directional rate of stimulated emission transitions $n \to m$, per unit volume
$R'_{ab,m\to n}$	directional rate of absorption transitions $m \to n$, per unit volume
R_{ki}	thermal resistance between kth surface and a nearby node at T_{ki}
R_k	$= \rho_k$ if k is T-specified and $= 1$ if it is q-specified
$\mathbf{r}$	position vector: $\mathbf{r} = (x, y, z)$
r_e, r_{eDC}	electrical resistivity, DC electrical resistivity
$\mathbf{r}_\lambda$	reflectivity matrix
$\mathbf{r}_k$	position vector of a point on surface k
S, S_j	surface, surface j
S'_E, S'_λ	source term in the RTE
$S'_{\lambda,i}$, $(S'_{\lambda,o})$	contribution to S'_λ due to inscattering (outscattering)
S_l, $\overline{S}$	line strength of l^{th} line, average line strength
$\overline{S}_0$	average line strength at the band center
s	distance measured along a ray
s, $s\,(\mathbf{u}, \mathbf{u}^*)$	distance between two points $\mathbf{u}$ and $\mathbf{u}^*$on an enclosure

s_{k-j}	distance between a point on k and a point on j
$\bar{s}_{k-j}$	mean beam length between surfaces j and k
$\bar{s}_{k-j,o}$	geometric mean beam length between j and k
T	temperature
T_g	gas temperature
T_s	surface temperature
T_j	temperature of surface j, $j = 1, 2..k....N$
T_k	temperature of surface k, $k = 1, 2..j....N$
T_{ki}	temperature of i^{th} node exchanging nonradiative heat with k
$\bar{T}_k$	mean temperature of surface k
t	time
$t_\lambda(s)$	optical thickness
t_f	film thickness of a composite surface
u, v	parameters relevant to a parametric surface representation
$\mathbf{u}$, (u, v)	vector with components u and v; $\mathbf{u}$ fixes a point on a surface
$\mathbf{u}_k$	$\mathbf{u}$ fixing a point on the kth surface
u	dimensionless path length, $= \overline{S}_0 s/\delta$
V	volume
V_p	particle volume
X	any extensive measure of the radiant field
x, y, z	Cartesian coordinates in space

Greek Letters

α'_λ	absorptivity of a surface
α'	total absorptivity
$\alpha'_{\lambda n}$	normal absorptivity (applies when incident ray is normal)
$\alpha\,(T)$, $\alpha_b\,(T)$	tabulated function of T, see Tables 21.4 and 21.5
$\alpha_{g,j}(s)$	total gas absorptivity
β	exponential wide-band's line width to spacing parameter
β	angle measured from the x-axis
γ, γ_0	electrical permittivity, electrical permittivity of free space
γ	opening angle of a V-corrugated surface
$\gamma(T)$, $\gamma_b(T)$	tabulated function of T, see Tables 21.6, and 21.7
δ, δ_l	line spacing, line spacing of l^{th}line
$\overline{\delta}_l$	mean line spacing
$\delta_{i,j}$	Kronecker delta function: $= 1$ if $i = j$; $= 0$ otherwise
ϵ'_λ	emissivity
$\epsilon'_{\lambda n}$	normal emissivity
ϵ_λ $(\epsilon_{\lambda k})$	hemispherical emissivity (of kth surface)
ϵ	total hemispheric emissivity
ϵ_k	total hemispheric emissivity of surface k

ϵ'	total directional emissivity
ϵ'_n	total normal emissivity
ϵ	total hemispheric emissivity
$\boldsymbol{\epsilon}_\lambda$	emissivity matrix
$\epsilon_g(s)$	total gas emissivity
ϵ_{soot}	soot emissivity
$\boldsymbol{\epsilon}$	total emissivity matrix
$\boldsymbol{\epsilon}_s$, $\boldsymbol{\epsilon}_t$	emissivity matrices for enclosures with q-specified surfaces
$\boldsymbol{\epsilon}^s$	specular total emissivity matrix
η	wave number
η_l	wave number at center of l^{th} line
$\bar{\eta}_b$, η_c	wave number at center of vibration rotation band
η^*	dimensionless wave number distance from center of smoothed band
θ, θ_k	angle from surface normal, angle from normal to the kth surface
θ	colatitude angle; with φ, angle specifying a direction $\hat{\mathbf{d}}$; angle between $\hat{\mathbf{d}}$ and $\hat{\mathbf{k}}$ or between $\hat{\mathbf{d}}$ and $\hat{\mathbf{n}}$
θ	(in scattering) the angle between two directions, $\hat{\mathbf{d}}$ and $\hat{\mathbf{d}}'$
θ_{1i}, θ_i	angle of incidence
$\theta_{1,r}$	(for smooth surface) angle of reflection at interface 1-2
θ_{2t}	(for smooth surface) angle of refraction
θ_B	Brewster angle
$\theta_{\max}$	angle of total internal reflection
θ_r	(for rough surface) angle of reflected direction considered, from normal
$\theta(\eta^*)$	function used for characterizing the smoothed band
θ, θ_2	dimensionless absolute temperatures, $\theta .= T/T_1$; $\theta_2 = T_2/T_1$
κ	absorption index
λ_a, λ	wavelength, free-space wavelength
μ, μ_0	magnetic permeability, magnetic permeability of free space
μ	$\cos\beta$
ν	frequency of electromagnetic wave
ρ'_λ	surface reflectivity
$\rho'_{\lambda n}$	reflectivity for radiation incident normal to surface
ρ''_λ	bidirectional reflectivity
ρ'	total reflectivity
ρ_λ, $\rho_{\lambda k}$	hemispheric reflectivity, hemispheric reflectivity of kth surface
ρ, ρ_k	total hemispheric reflectivity, total hemispheric reflectivity of k
ρ	gas density
σ	Stefan-Boltzmann constant
σ_λ	scattering coefficient
φ	azimuth angle; with θ, angle specifying a direction $\hat{\mathbf{d}}$

φ_r	azimuth angle of reflected direction considered
φ_b, φ_g	dimensionless temperatures given by Eqs. (23.19) and (23.27)
χ	alternate symbol for θ_{2t}
ω, ω_j	solid angle, solid angle subtended by surface j
ω	bandwidth of an exponential wide band
ω_0	wide band property tabulated in Table 21.3
$\Phi\left(\hat{\mathbf{d}}, \hat{\mathbf{d}}'\right)$	phase function relevant to scattering