SYMBOLS

\( A \)  
- surface area

\( A_{n \rightarrow m} \)  
- Einstein Coefficient of spontaneous emission

\( A_b(s) \)  
- effective bandwidth

\( a \)  
- mean absorption coefficient; gray-medium absorption coefficient

\( a_\lambda, a_\eta \)  
- absorption coefficient

\( a_\eta^* \)  
- 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

\( B_k(\mathbf{u}_k) \)  
- 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

\( d \)  
- unit vector indicating a particular direction in space

\( d \)  
- number of diffuse surfaces in a specular enclosure

\( E \)  
- electric field intensity

\( E_x, E_y, E_z \)  
- components of \( E \)

\( E_0 \)  
- amplitude of a sinusoidal electric field

\( E \)  
- energy of a photon

\( E_{nm} \)  
- \( e_n - e_m \)

\( E_{\perp}, E_{\parallel} \)  
- components of \( E \) 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

\( e, \lambda \)  
- emissive power

\( e_{\lambda b}, e_{\lambda b} \)  
- blackbody emissive power

\( e \)  
- total emissive power
total blackbody emissive power
\( \varepsilon_{\lambda k}, \varepsilon_{\eta k} \) evaluated at temperature \( T_k \)
unit vector along a line joining two points on an enclosure surface
blackbody vector; its elements are the set of \( \varepsilon_{\lambda k} \)'s
point form factor from elemental area \( d_i \) to surface \( j \)
form factor from surface \( i \) to surface \( j \)
( universal ) fractional blackbody energy function
form factor matrix with elements \( F_{i-j} \)
specular form factor from surface \( k \) to surface \( j \)
specular form factor matrix with elements \( F^s_{k-j} \)
exchange factor from surface \( k \) to surface \( j \)
total exchange factor from \( k \) to \( j \), for temperature \( T \)
exchange factor matrix
specular enclosure exchange factor from \( k \) to \( j \)
specular enclosure exchange factor matrix
gaseous exchange factor matrix
fraction of \( \varepsilon_{\lambda} \) at temperature \( T \) with wavelength \( \leq \lambda \)
fraction of \( \varepsilon_{\lambda} \) at temperature \( T \) with wavelength between \( \lambda_1 \) and \( \lambda_2 \)
volume fraction of a sooty gas occupied by soot particles
gaseous point form factor ( function ) from area \( d_i \) to surface \( j \)
gaseous form factor ( function ) from surface \( k \) to surface \( j \)
solar constant
matrix of gaseous form factor functions
magnetic field intensity
components of \( \mathbf{H} \)
amplitude of a sinusoidal variation in \( \mathbf{H} \)
hemispherical solid angle bisected by \( \hat{n} \) or \( \hat{k} \)
Planck’s constant
convective heat transfer coefficient
radiative heat transfer coefficient between surfaces \( k \) and \( j \)
identity matrix
number of image surfaces in a specular enclosure
quantum state number
intensity
blackbody intensity
blackbody intensity inside medium of index of refraction \( n \)
total intensity, total blackbody intensity
unit vector along \( x \)-axis
surface factor for a parametric surface, \( = |\mathbf{J}(u,v)| \)
surface normal for a parametric surface
**SYMBOLS**

\( j \) integer representing a particular enclosure surface

\( \hat{j} \) 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

\( \hat{k} \) 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

\( M \) 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

\( N \) 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

\( \hat{n} \) 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

\( P_{H_2O} \) partial pressure of \( H_2O \)

\( P_{CO_2} \) partial pressure of \( CO_2 \)

\( Q_{r\lambda} \) radiant heat flow over a finite surface

\( Q_r \) total rate at which radiative heat leaves surface \( k \)

\( Q_{\eta} \) 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
total radiant heat flux
partial radiant heat flux
net radiant heat flux
average radiant heat flux over surface \( k \)
vector of radiant heat fluxes
components of \( q \)
rate per unit volume at which radiant energy leaves medium
(spectral) surface heat flux
surface heat flux
outgoing radiant heat flux at surface \( k \)
average outgoing radiant heat flux at surface \( k \)
total outgoing radiant heat flux at surface \( k \)
vector of average outgoing radiant heat fluxes
vector of total average outgoing radiant heat fluxes
spectral heat flow vector
total heat flow vector
rate of spontaneous emissions \( n \rightarrow m \), per unit volume
rate of stimulated emissions \( n \rightarrow m \), per unit volume
rate of absorption transitions \( m \rightarrow n \), per unit volume
radius
directional rate of spontaneous emission transitions \( n \rightarrow m \), per unit volume
directional rate of stimulated emission transitions \( n \rightarrow m \), per unit volume
directional rate of absorption transitions \( m \rightarrow n \), per unit volume
thermal resistance between \( k \)th surface and a nearby node at \( T_{ki} \)
= \( \rho_{k} \) if \( k \) is \( T \)-specified and = 1 if it is \( q \)-specified
position vector: \( r = (x, y, z) \)
electrical resistivity, DC electrical resistivity
reflectivity matrix
position vector of a point on surface \( k \)
surface, surface \( j \)
source term in the RTE
contribution to \( S'_{\lambda} \) due to incsattering (outscattering)
line strength of \( l \)th line, average line strength
average line strength at the band center
distance measured along a ray
distance between two points \( u \) and \( u^* \) on an enclosure
**SYMBOLS**

$s_{k-j}$ 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 $j$, $j = 1, 2, k, \ldots, N$

$T_k$ temperature of surface $k$, $k = 1, 2, j, \ldots, N$

$T_{k_i}$ 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

$u, (u, v)$ vector with components $u$ and $v$; $u$ fixes a point on a surface

$u_k$ $u$ fixing a point on the $k$th surface

$u$ dimensionless path length, $= \overline{s_0}/\delta$

$V$ volume

$V_p$ particle volume

$X$ any extensive measure of the radiant field

$x, y, z$ Cartesian coordinates in space

**Greek Letters**

$\alpha'_{\lambda}$ absorptivity of a surface

$\alpha'$ 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

$\beta$ exponential wide-band’s line width to spacing parameter

$\beta$ angle measured from the $x$-axis

$\gamma, \gamma_0$ electrical permittivity, electrical permittivity of free space

$\gamma$ opening angle of a V-corrugated surface

$\gamma(T), \gamma_b(T)$ tabulated function of $T$, see Tables 21.6, and 21.7

$\delta, \delta_l$ 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

$\varepsilon'_{\lambda}$ emissivity

$\varepsilon_{\lambda n}$ normal emissivity

$\varepsilon_{\lambda} (\varepsilon_{\lambda k})$ hemispherical emissivity (of $k$th surface)

$\varepsilon$ total hemispheric emissivity

$\varepsilon_k$ total hemispheric emissivity of surface $k$
\( \epsilon' \) total directional emissivity
\( \epsilon'_{n} \) total normal emissivity
\( \epsilon \) total hemispheric emissivity
\( \epsilon_{\lambda} \) emissivity matrix
\( \epsilon_{g}(s) \) total gas emissivity
\( \epsilon_{\text{soot}} \) soot emissivity
\( \epsilon \) total emissivity matrix
\( \epsilon_{s, \text{sp}} \) emissivity matrices for enclosures with \( q \)-specified surfaces
\( \epsilon^{s} \) specular total emissivity matrix
\( \eta \) wave number
\( \eta_{l} \) wave number at center of \( l^{th} \) line
\( \eta_{b}, \eta_{c} \) wave number at center of vibration rotation band
\( \eta^{*} \) dimensionless wave number distance from center of smoothed band
\( \theta, \theta_{k} \) angle from surface normal, angle from normal to the \( k \)th surface
\( \theta \) colatitude angle; with \( \varphi \), angle specifying a direction \( \hat{d} \); angle between \( \hat{d} \) and \( \hat{k} \) or between \( \hat{d} \) and \( \hat{n} \)
\( \theta_{1}, \theta_{2} \) angle of incidence
\( \theta_{r} \) (for smooth surface) angle of reflection at interface 1-2
\( \theta_{2} \) (for smooth surface) angle of refraction
\( \theta_{B} \) Brewster angle
\( \theta_{\text{max}} \) angle of total internal reflection
\( \theta^{*} \) (for rough surface) angle of reflected direction considered, from normal
\( \theta_{1}^{*} \) function used for characterizing the smoothed band
\( \theta, \theta_{2} \) dimensionless absolute temperatures, \( \theta = T/T_{1} \); \( \theta_{2} = T_{2}/T_{1} \)
\( \kappa \) absorption index
\( \lambda_{a}, \lambda \) wavelength, free-space wavelength
\( \mu, \mu_{0} \) magnetic permeability, magnetic permeability of free space
\( \mu \cos \beta \)
\( \nu \) frequency of electromagnetic wave
\( \rho'_{\lambda} \) surface reflectivity
\( \rho'_{\lambda n} \) reflectivity for radiation incident normal to surface
\( \rho'_{\lambda k} \) bidirectional reflectivity
\( \rho' \) total reflectivity
\( \rho_{\lambda}, \rho_{\lambda k} \) hemispheric reflectivity, hemispheric reflectivity of \( k \)th surface
\( \rho, \rho_{k} \) total hemispheric reflectivity, total hemispheric reflectivity of \( k \)
\( \rho \) gas density
\( \sigma \) Stefan-Boltzmann constant
\( \sigma_{\lambda} \) scattering coefficient
\( \varphi \) azimuth angle; with \( \theta \), angle specifying a direction \( \hat{d} \)
\( \varphi_r \) azimuth angle of reflected direction considered
\( \varphi_b, \varphi_g \) dimensionless temperatures given by Eqs. (23.19) and (23.27)
\( \chi \) alternate symbol for \( \theta_{2l} \)
\( \omega, \omega_j \) solid angle, solid angle subtended by surface \( j \)
\( \omega \) bandwidth of an exponential wide band
\( \omega_0 \) wide band property tabulated in Table 21.3
\( \Phi \left( \mathbf{d}, \mathbf{d}' \right) \) phase function relevant to scattering