Nomenclature

NOTATION

$\bar{f}$ = principle-axis version of f, background or quiescent-fluid value of f, or average or ensemble average of f

$\widehat{f}$ = complex amplitude of f

$\tilde{f}$ = full field value of f

f' = derivative of f with respect to its argument, or perturbation of f from its reference state

f^* = complex conjugate of f, dimensionless version of f, or the value of f at the sonic condition

f^+ = the dimensionless, law-of-the-wall value of f

f_{cr} = critical value of f

f_{CL} = centerline value of f

f_0 = reference, surface, or stagnation value of f

f_∞ = reference value of f or value of f far away from the point of interest

Δf = change in f

SYMBOLS*

α = contact angle, thermal expansion coefficient (1.20), angle of rotation, angle of attack, Womersley number (16.12), angle in a toroidal coordinate system, area ratio

a = triangular area, cylinder radius, sphere radius, amplitude

*Relevant equation numbers appear in parentheses

a_0 = initial tube radius

$\mathbf{a}$ = generic vector, Lagrangian acceleration (3.1)

$\mathbf{A}$ = generic second-order (or higher) tensor

A, A = a constant, an amplitude, area, surface, surface of a material volume, planform area of a wing

A^* = control surface, sonic throat area

A_o = Avogadro's number

A_0 = reference area

A_{ij} = representative second-order tensor

β = angle of rotation, coefficient of density change due to salinity or other constituent, variation of the Coriolis frequency with latitude, camber parameter

$\mathbf{b}$ = generic vector, control surface velocity (3.35)

B, B = a constant, Bernoulli function (4.70), log-law intercept parameter (12.88)

$\mathbf{B}$, B_{ij} = generic second-order (or higher) tensor

Bo = Bond number (4.118)

c = speed of sound (1.19, 15.6), phase speed (7.4), chord length (14.2), pressure pulse wave speed, concentration of solutes

c_j = pressure pulse wave speed in tube j

$\mathbf{c}$ = phase velocity vector (7.8)

c_g, $\mathbf{c_g}$ = group velocity magnitude (7.68) and vector (7.144)

χ = scalar stream function

°C = degrees centigrade

C = a generic constant, hypotenuse length, closed contour

Ca = Capillary number (4.119)

C_f = skin friction coefficient (9.32)

C_p = coefficient of pressure (4.106, 6.32)

C_p = specific heat capacity at constant pressure (1.14)
C_D = coefficient of drag (4.107, 9.33)
C_L = coefficient of lift (4.108)
C_v = specific heat capacity at constant volume (1.15)
C_{ij} = matrix of direction cosines between original and rotated coordinate system axes (2.5)
d = diameter, distance, fluid layer depth
$\mathbf{d}$ = dipole strength vector (6.29), displacement vector
δ = Dirac delta function (B.4.1), similarity-variable length scale (8.32), boundary-layer thickness, generic length scale, small increment, flow deflection angle (15.53), tube radius divided by tube radius of curvature
$\overline{\delta}$ = average boundary-layer thickness
δ^* = boundary-layer displacement thickness (9.16)
δ_{ij} = Kronecker delta function (2.16)
δ_{99} = 99% layer thickness
D = distance, drag force, diffusion coefficient, Dean number (16.179)
D_i = lift-induced drag (14.15)
D/Dt = material derivative (3.4) or (3.5)
D_T = turbulent diffusivity of particles (12.127)
$\mathcal{D}$ = generalized field derivative (2.31)
ε = roughness height, kinetic energy dissipation rate (4.58), a small distance, fineness ratio h/L (8.14), downwash angle (14.14)
$\overline{\varepsilon}$ = average dissipation rate of the turbulent kinetic energy (12.47)
$\overline{\varepsilon}_T$ = average dissipation rate of the variance of temperature fluctuations (12.112)
ε_{ijk} = alternating tensor (2.18)
e = internal energy per unit mass (1.10)
$\mathbf{e}_i$ = unit vector in the i-direction (2.1)
$\overline{e}$ = average kinetic energy of turbulent fluctuations (12.47, 12.49)
Ec = Eckert number (4.115)
E_k = kinetic energy per unit horizontal area (7.39)
E_p = potential energy per unit horizontal area (7.41)
E = average energy per unit horizontal area (7.43), Ekman number (13.18), Young's modulus
$\overline{E}$ = kinetic energy of the average flow (12.46)
$\widehat{E}_1$ = total energy dissipation in a blood vessel
f = generic function, Helmholtz free energy per unit mass, longitudinal correlation coefficient (12.38), Coriolis frequency (13.8), dimensionless friction parameter (15.45)
ϕ = velocity potential (6.10), an angle
$\mathbf{f}$ = surface force vector per unit area (2.15, 4.13)
F = force magnitude, generic flow field property, average energy flux per unit length of wave crest (7.44), generic or profile function
$\mathbf{F}$ = force vector, average wave energy flux vector
$\mathbf{\Phi}$ = body force potential (4.18), undetermined spectrum function (12.53)
F_D = drag force
F_L = lift force
Fr = Froude number (4.104)
γ = ratio of specific heats (1.24), velocity gradient, vortex sheet strength, generic dependent-field variable
$\dot{\gamma}$ = shear rate
$\mathbf{g}$ = body force per unit mass (4.13)
g = acceleration of gravity, undetermined function, transverse correlation coefficient (12.38)
g' = reduced gravity (7.188)
$\mathbf{\Gamma}$ = vertical temperature gradient or lapse rate, circulation (3.18)
Γ_a = adiabatic vertical temperature gradient (1.30)
Γ_a = circulation due to the absolute vorticity (5.33)

G = gravitational constant, pressure-gradient pulse amplitude, profile function
G_n = Fourier series coefficient
G = center of mass, center of vorticity
h = enthalpy per unit mass (1.13), height, gap height, viscous layer thickness, grid size, tube wall thickness
η = free surface shape, waveform, similarity variable (8.25, 8.32), Kolmogorov microscale (12.50), radial tube-wall displacement
η_T = Batchelor microscale (12.114)
H = atmospheric scale height, water depth, shape factor (9.46), profile function, Hematocrit
i = an index, imaginary root
I = incident light intensity, bending moment of inertia
j = an index
J, J_s = jet momentum flux per unit span (9.61)
J_i = Bessel function of order i
$\mathbf{J}_m$ = diffusive mass flux vector (1.1)
φ = a function, azimuthal angle in cylindrical and spherical coordinates
k = thermal conductivity (1.2), an index, wave number (7.2), wave number component
κ = thermal diffusivity, von Karman constant (12.88), Dean number (16.171)
κ_s = diffusivity of salt
κ_T = turbulent thermal diffusivity (12.95)
κ_m = mass diffusivity of a passive scalar in Fick's law (1.1)
κ_{mT} = turbulent mass diffusivity (12.96)
k_B = Boltzmann's constant (1.21)
Kn = Knudsen number
K = a generic constant, magnitude of the wave number vector (7.6), lift curve slope, Dean Number (16.178)
K_p = constant proportional to tube wall bending stiffness
K = compliance of a blood vessel, degrees Kelvin (16.48)
$\mathbf{K}$ = wave number vector, stiffness matrix
l = molecular mean free path, spanwise dimension, generic length scale, wave number component (7.5, 7.6), shear correlation in Thwaites method (9.45), length scale in turbulent flow
l_T = mixing length (12.98)
L, L = generic length dimension, generic length scale, lift force
L_M = Monin-Obukhov length scale (12.110)
λ = wavelength (7.1, 7.7), laminar boundary-layer correlation parameter (9.44), flow resistance ratio
λ_m = wavelength of the minimum phase speed
λ_t = temporal Taylor microscale (12.19)
λ_f, λ_g = longitudinal and lateral spatial Taylor microscale (12.39)
Λ = lubrication-flow bearing number (8.16), Rossby radius of deformation, wing aspect ratio
Λ_f, Λ_g = longitudinal and lateral integral spatial scales (12.39)
Λ_t = integral time scale (12.18)
μ = dynamic or shear viscosity (1.3), Mach angle (15.49)
μ_v = bulk viscosity (4.37)
m = molecular mass (1.22), generic mass, an index, two-dimensional source strength, moment order (12.1), wave number component (7.5, 7.6)
M, M = generic mass dimension, mass, Mach number (4.111), apparent or added mass (6.108)
M_w = molecular weight
n = number of molecules (1.21), an index, generic integer number
$\mathbf{n}$ = normal unit vector
n_s = index of refraction
N = Brunt-Väisälä or buoyancy frequency (1.29, 7.128), number, number of pores in a sieve plate
N_A = basis or interpolation functions
ν = kinematic viscosity (1.4), cyclic frequency, Prandtl-Meyer function (15.56)

ν_T = turbulent kinematic viscosity (12.94)
$\widehat{\nu}$ = Poisson's ratio
O = origin
p = pressure
p_{atm} = atmospheric pressure
p_i = inside pressure
p_o = outside pressure
p_0 = reference pressure at $z = 0$
p_∞ = reference pressure far upstream or far away
$\overline{p}$ = average or quiescent pressure in a stratified fluid
P = average pressure
P = normalized pressure in a collapsible tube
Π = wake strength parameter
Pr = Prandtl number (4.116)
$\mathbf{q}$, q_i = heat flux (1.2)
q_n = generic parameter in dimensional analysis
q = heat added to a system (1.10), volume flux per unit span, dimensionless heat addition parameter (15.45)
Q = thermodynamic heat per unit mass, volume flux in two or three dimensions
θ = potential temperature (1.31), unit of temperature, angle in polar coordinates, momentum thickness (9.17), local phase, an angle, angle in a toroidal coordinate system
ρ = mass density (1.1)
ρ_m = mass density of a mixture
$\overline{\rho}$ = average or quiescent density in a stratified fluid
ρ_θ = potential density (1.33)
r = matrix rank, distance from the origin, distance from the axis
$\mathbf{r}$ = particle trajectory (3.1, 3.8)
R = distance from the cylindrical axis, radius of curvature, gas constant (1.23), generic nonlinearity parameter, total peripheral resistance (16.9), tube radius of curvature
R = viscous resistance per unit length, reflection coefficient (16.204), (16.153)
R_u = universal gas constant (1.22)
R_i = radius of curvature in direction i (1.5)
$\mathbf{R}$, R_{ij} = rotation tensor (3.13), correlation tensor (12.13, 12.23)
Ra = Rayleigh number (11.21)
Re = Reynolds number (4.103)
Ri = Richardson number, gradient Richardson number (11.66, 12.108)
Rf = flux Richardson number (12.107)
Ro = Rossby number (13.13)
σ = surface tension (1.5), interfacial tension, vortex core size (3.28, 3.29), temporal growth rate (11.1), shock angle
s = entropy (1.16), arc length, salinity, wingspan (14.1), dimensionless arc length
σ_{ij} = viscous stress tensor (4.27)
S = salinity, scattered light intensity, an area, dimensionless speed index, entropy
S_e = one-dimensional temporal longitudinal energy spectrum (12.20)
S_{11} = one-dimensional spatial longitudinal energy spectrum (12.45)
S_T = one-dimensional temperature fluctuation spectrum (12.113, 12.114)
$\mathbf{S}$, S_{ij} = strain rate tensor (3.12), symmetric tensor
St = Strouhal number (4.102)
t = time
$\mathbf{t}$ = tangent vector
T, T = temperature (1.2), generic time dimension, period, transmission coefficient (16.153)
Ta = Taylor number (11.52)
T_o = free stream temperature
T_w = wall temperature
T_i = tension in the i-direction
τ = shear stress (1.3), time lag
$\boldsymbol{\tau}$, τ_{ij} = stress tensor (2.15)
τ_0 = wall or surface shear stress
υ = specific volume = $1/\rho$
u = horizontal component of fluid velocity (1.3)
$\mathbf{u}$ = generic vector, fluid velocity vector (3.1)

u_i = fluid velocity components, fluctuating velocity components
u_* = friction velocity (12.81)
$\mathbf{U}$ = generic uniform velocity vector
U_i = ensemble average velocity components
U = generic velocity, average stream-wise velocity
ΔU = characteristic velocity difference
U_e = local free-stream flow speed above a boundary layer (9.11), flow speed at the effective angle of attack
U_{CL} = centerline velocity (12.56)
U_∞ = flow speed far upstream or far away
v = component of fluid velocity along the y axis
$\mathbf{v}$ = generic vector
V = volume, material volume, average stream-normal velocity, average velocity, variational space, complex velocity
V^* = control volume
w = complex potential (6.42), vertical component of fluid velocity, function in the variational space, downwash velocity (14.13)
W = thermodynamic work per unit mass, wake function
$\dot{W}$ = rate of energy input from the average flow (12.49)
We = Weber number (4.117)
ω = temporal frequency (7.2)
$\boldsymbol{\omega}$, ω_i = vorticity vector (3.16)
Ω = oscillation frequency, computational domain, rotation rate, rotation rate of the earth
$\boldsymbol{\Omega}$ = angular velocity of a rotating frame of reference
x = first Cartesian coordinate
$\mathbf{x}$ = position vector (2.1)
x_i = components of the position vector (2.1)
ξ = generic spatial coordinate, integration variable, similarity variable (12.84), axial tube wall displacement
y = second Cartesian coordinate
Y = mass fraction (1.1)
Y_{CL} = centerline mass fraction (12.69)
Y_i = Bessel function of order i, admittance
ψ = stream function (6.3, 6.75), water potential
Ψ = Reynolds stress scaling function (12.57), generic functional solution
$\boldsymbol{\Psi}$ = vector potential, three-dimensional stream function (4.12)
z = third Cartesian coordinate, complex variable (6.43)
ζ = interface displacement, angular tube-wall displacement, relative vorticity
Z = impedance (16.151)