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A COMPILATION OF NONDIMENSIONAL NUMBERS

Norman S. Land

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Introduction

The purpose of this compilation is to provide a ready means of identifying the named nondimensional numbers that are used in the various technical areas. The compilation probably contains most of the named nondimensional numbers that might be encountered. It also contains a few unnamed numbers that seem to be frequently used in certain fields. No claim to completeness is made, since the compilation represents mainly the "private collection" of the author rather than the result of an extensive and systematic search of the technical literature. In order to allow for expansion by each user in his particular field of interest, generous page margins have been provided, along with several blank pages (pp. 106–114).

In this compilation, the nondimensional numbers are listed in alphabetical order. (The few that are unnamed are designated as "No Name" and listed under N.) Each is defined in terms of common physical quantities, the dimensions of which are also given. In addition, wherever pertinent, the nondimensional number is also defined as a ratio of similar quantities (e.g., Reynolds number ~ pressure force/viscous force). The typical field of application is usually included, together with any additional remarks or clarification that may help the user. Finally, a reference is given to some source in which the number is used. This source is not necessarily the most basic one with regard to the number, but it should, through its own literature citations, serve as a starting point for further study.

The bibliography contains a short list of general references in the theory of modeling, dimensions, and units. The terminology and symbols used in the references, which frequently represent normal usage in the particular field, have been altered in some cases in order to provide uniformity of notation in the present compilation.

A small index (in which the nondimensional numbers have been grouped according to area of application) along with the references and bibliography appear after the compilation of nondimensional numbers.

SOME QUANTITIES AND THEIR DIMENSIONS

The following table lists the various quantities that are used in defining the nondimensional numbers. The dimensions of these quantities

are given in the so-called physical system. In this system, the basic mechanical dimensions are: mass, m; length, ℓ; and time, t. For thermal quantities, it is necessary to add temperature, T; and for electrical quantities, electrical charge, Q, is added. If quantities involving luminosity should be needed, the dimension of luminous intensity would be a possibility for the necessary additional dimensions.

Other dimensional systems than the physical system are given and discussed by Weber in Eshbach's "Handbook of Engineering Fundamentals."

Physical Quantities, Symbols, and Dimensions

Quantity	Symbol	Physical dimensions	Units in common use	
General and mechanical:				
Area	A	ℓ^2	feet^2	meters^2
Acceleration	a	ℓ/t^2	g's, feet/second^2	meters/second^2
Density, mass	ρ	m/ℓ^3	slugs/foot^3	kilograms/meter^3
Density, weight	w	m/ℓ^2t^2	pounds/foot^3	newtons/meter^3
Energy	E	$m\ell^2/t^2$	BTU, foot-pound, watt-hour	joule (newton-meter)
Flow rate, mass	Q_m	m/t	slugs/second	kilogram/second
Flow rate, volume	Q_v	ℓ^3/t	feet^3/minute	meters^3/second
Flow rate, weight	Q_w	$m\ell/t^3$	pounds/hour	newtons/second
Force	F	$m\ell/t^2$	pounds	newtons
Frequency	f	$1/t$	second^{-1}	second^{-1}
Gravitational constant		ℓ^3/mt^2		
Length	ℓ	ℓ	foot	meter
Mass	m	m	slug	kilogram
Modulus of elasticity	G, E	$m/\ell t^2$	pounds/inch^2	newtons/meter^2
Momentum	M	$m\ell/t$	slug foot/second	kilogram meter/second
Permeability	k	ℓ^2	darcys	meters^2
Power	P	$m\ell^2/t^3$	horsepower	watt (joule/second)
Pressure	p	$m/\ell t^2$	pounds/inch^2, Torr	newton/meter^2
Speed	V	ℓ/t	feet/second, miles/hour	meter/second
Stress	σ	$m/\ell t^2$	pounds/inch^2	newtons/meter^2
Surface tension	σ	m/t^2	pounds/inch	newtons/meter
Time	t	t	seconds	seconds
Velocity, angular	ω	$1/t$	seconds^{-1}	seconds^{-1}
Velocity, linear	V	ℓ/t	feet/second, miles/hour	meters/second

Physical Quantities, Symbols, and Dimensions — Continued

Quantity	Symbol	Physical Dimensions	Units in common use	
Viscosity, absolute	μ	$m/\ell t$	slugs/foot second, poises	newton second/meter^2
Viscosity, kinematic	ν	ℓ^2/t	feet^2/second, stokes	meters^2/second
Volume	V	ℓ^3	feet^3	meters^3
Weight	W	$m\ell/t^2$	pounds	newtons
Work	W	$m\ell^2/t^2$	pound-feet	newton-meters
Thermal:				
Entropy	S	$m\ell^2/t^2T$	BTU/degree F	calories/degree C
Heat	H	$m\ell^2/t^2$	BTU	calories, joules
Heat conductivity	k	$m\ell/t^3T$	BTU/foot second degree F	calories/centimeter second degree C
Heat transfer coefficient	h	m/t^3T	BTU/foot^2 second degree F	calories/centimeter^2 second degree C
Specific heat	C_p, C_v	ℓ^2/t^2T	BTU/pound degree F	calories/gram degree C
Temperature	T	T	degrees F, R	degrees C, K
Diffusivity; mass, momentum, or energy		ℓ^2/t	feet^2/seconds	meter^2/second
Gas constant	R	ℓ^2/t^2T	feet^2/seconds^2 degree R	cal/degree-kg
Gas constant, universal	R	$m\ell^2/t^2T$	BTU/degree R	cal/degree K
Electrical:				
Current	I	Q/t	ampere	
Electric charge	Q	Q	coulomb	
Electrostatic flux		Q	coulomb	
Magnetic flux		$m\ell^2/Qt$	maxwell	weber
Magnetizing force (field intensity)	H	$Q/\ell t$	ampere/foot	oersted, ampere/meter
Magnetomotive force (magnetic potential)		Q/t	ampere turn	gilbert

Magnetic induction (flux density)	B	m/Qt	maxwells/inch^2	gauss, tesla
Magnetic permeability	μ	$m\ell/Q^2$		
Dielectric constant (permittivity)		$Q^2t^2/m\ell^3$		
Reluctance		$Q^2/m\ell^2$		
Resistance	R	$m\ell^2/Q^2t$	ohm	
Voltage	E	$m\ell^2/Qt^2$	volt	
Conductivity	σ	Q^2t/ml^3	mho/cm	
Electric field strength		ml/Qt^2	volts/cm	

Nondimensional Numbers

ACCELERATION

$$\frac{E_b^3}{\rho g^2 \mu^2}$$

E_b, bulk modulus of fluid, $m/\ell t^2$
ρ, mass density, m/ℓ^3
g, gravitational acceleration, ℓ/t^2
μ, absolute viscosity, $m/\ell t$
Accelerated flow
Ref. 30

ALFVEN

$$\frac{\text{Flow speed}}{\text{Alfvén wave speed}}$$

$$\frac{V(\rho\mu)^{1/2}}{B}$$

V, flow speed, ℓ/t
ρ, mass density, m/ℓ^3
μ, magnetic permeability, $m\ell/Q^2$
B, magnetic induction, m/Qt
Magnetohydrodynamics
Equals Magnetic Mach, 1/Cowling
Ref. 2

ARCHIMEDES

$$\frac{\text{Buoyant force}}{\text{Viscous force}}$$

$$\frac{g\ell^3\Delta\rho}{\rho\nu^2}$$

g, gravitational acceleration, ℓ/t^2
ℓ, length, ℓ
$\Delta\rho$, mass density difference, m/ℓ^3
ρ, mass density, m/ℓ^3
ν, kinematic viscosity, ℓ^2/t
Two medium flow, fluidization
Ref. 1

ARRHENIUS

$$\frac{\text{Activation energy}}{\text{Potential energy}}$$

$$\frac{E_a}{RT}$$

E_a, activation energy, ℓ^2/t^2
R, gas constant, ℓ^2/t^2T
T, temperature, T
Reaction rates
Ref. 30

BAGNOLD

$$\frac{\text{Air drag on particle}}{\text{Weight of particle}}$$

$$\frac{3C_R\rho_g V^2}{4d\rho_p g}$$

C_R, air drag coefficient of particle, 1
ρ_g, mass density of gas, m/ℓ^3
V, velocity of gas, ℓ/t
d, particle diameter, ℓ
ρ_p, mass density of particle, m/ℓ^3
g, gravitational acceleration, ℓ/t^2
Wind erosion of soil
Saltation
Ref. 32

BANSEN

$$\frac{\text{Heat radiated}}{\text{Heat capacity of fluid}}$$

$$\frac{h_r A}{Q_m c}$$

h_r, radiant heat transfer coefficient, m/t^3T
A, area, ℓ^2
Q_m, mass flow rate, m/t
c, specific heat, ℓ^2/t^2T
Radiation from flowing fluid
Ref. 30

BINGHAM

$$\frac{\text{Yield stress}}{\text{Viscous stress}}$$

$$\frac{\sigma \ell}{\mu V}$$

σ, stress at elastic yield, $m/\ell t^2$
ℓ, characteristic length, ℓ
μ, absolute viscosity in plastic state, $m/\ell t$
V, velocity, ℓ/t
Flow of plastics
Equals Hedstrom 2
Ref. 29, definition only

BIOT (heat transfer)

$$\frac{\text{Heat transfer body to fluid}}{\text{Heat transfer within body}}$$

$$\frac{h\ell}{k}$$

h, heat transfer coefficient, m/t^3T
ℓ, characteristic length, ℓ
k, heat conduction coefficient $m\ell/t^3T$
Temperature distribution of immersed body
Equals Nusselt
Ref. 1

BIOT (mass transfer)

$$\frac{\text{Mass transfer rate at interface}}{\text{Mass transfer rate in interior of wall}}$$

$$\frac{k_e \ell}{D_{\text{int}}}$$

k_e, mass transfer rate, ℓ/t
ℓ, wall thickness, ℓ
D_{int}, mass diffusivity at interface, ℓ^2/t
Mass transfer between fluid and solid
Ref. 30

BLAKE

$$\frac{\text{Inertia force}}{\text{Viscous force}}$$

$$\frac{\rho V}{\mu(1-e)S}$$

ρ, mass density, m/ℓ^3
V, velocity, ℓ/t
μ, absolute viscosity, $m/\ell t$
e, void ratio, volume of voids/volume of solids, 1
S, area-volume ratio of particles, $1/\ell$
Flow in particle beds
A modified Reynolds Number
Ref. 29, definition only

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BODENSTEIN

$$\frac{\text{Bulk mass transfer}}{\text{Diffusive mass transfer}}$$

$$\frac{V\ell}{D}$$

V, velocity, ℓ/t
ℓ, reactor length, ℓ
D, axial mass diffusivity, ℓ^2/t
Mass transfer
A special Peclet Number
Ref. 30

BOLTZMANN

$$\frac{\text{Bulk heat transport}}{\text{Radiative heat transport}}$$

$$\frac{\rho c_p V}{e\eta T^3}$$

ρ, mass density, m/ℓ^3
c_p, specific heat at constant pressure, ℓ^2/t^2T
V, velocity, ℓ/t
e, surface emissivity, 1
η, Stefan-Boltzmann constant, m/T^4t^3
T, temperature, T
Radiation
Equals Thring
Ref. 30

BOND

$$\frac{\text{Gravity force}}{\text{Surface tension force}}$$

$$\frac{\rho \ell^2 g}{\sigma}$$

ρ, mass density, m/ℓ^3
ℓ, characteristic length, ℓ
g, gravitational acceleration, ℓ/t^2
σ, surface tension, m/t^2
Capillary flow, sloshing
Equal to Weber/Froude
Equals Eötvös
See Deryagin
Ref. 16

BOUGUER

$$\frac{3C_D \lambda_r}{4\rho_D R}$$

C_D, mass of dust/bed volume, m/ℓ^3
λ_r, mean path length for radiation, ℓ
ρ_D, mass density of dust, m/ℓ^3
R, mean particle radius, ℓ
Radiant heat transfer to dust laden gas
Ref. 30

BOUSSINESQ

$$\frac{\text{Inertia force}}{\text{Gravity force}}$$

$$\frac{V}{(2gm)^{1/2}}$$

V, velocity, ℓ/t
g, gravitational acceleration, ℓ/t^2
m, hydraulic radius, wetted cross section area/wetted perimeter, ℓ
Waves in open channels
A modified Froude Number
Ref. 29, definition only

BRINKMAN

$$\frac{\text{Heat produced by viscous dissipation}}{\text{Heat transported by molecular conduction}}$$

$$\frac{\mu V^2}{kT}$$

μ, absolute viscosity, $m/\ell t$
V, velocity, ℓ/t
k, heat conductivity, $m\ell/t^3T$
T, temperature, T
Viscous flow
Ref. 11

BUBBLE NUSSELT

$$\frac{qD}{k\Delta T}$$

q, heat flux, heat/area time, m/t^3
D, bubble diameter, ℓ
k, heat conductivity of liquid, $m\ell/t^3T$
ΔT, surface temperature minus saturation temperature, T
Boiling
Ref. 10

BUBBLE REYNOLDS

$$\frac{DG}{\mu}$$

D, bubble diameter, ℓ
μ, absolute viscosity, $m/\ell t$
$G = \frac{\pi}{6} D^3 \rho_v f n$, $m/\ell^2 t$
ρ_v, mass density of vapor m/ℓ^3
f, frequency of formation, $1/t$
n, number of nucleation centers/area, $1/\ell^2$
Boiling
Ref. 10

BULYGIN

$$\frac{\text{Heat to vaporize liquid}}{\text{Heat to bring liquid to boiling}}$$

Heat transfer during evaporation
Ref. 29, definition only

BUOYANCY

$$\frac{\text{Buoyant force}}{\text{Viscous force}}$$

$$\frac{\ell^2 W \beta \Delta T}{\mu V V}$$

ℓ, characteristic length, ℓ
W, weight, $m\ell/t^2$
β, temperature coefficient of volume expansion, $1/T$
ΔT, temperature differential, T
μ, absolute viscosity, $m/\ell t$
V, volume, ℓ^3
V, velocity, ℓ/t
Convection, buoyancy
Ref. 16

CAPILLARITY 1

$$\frac{\text{Capillary force}}{\text{Filtration force}}$$

$$\frac{\sigma k^{1/2}}{\mu V \ell}$$

σ, interfacial tension, m/t^2
k, permeability, ℓ^2
μ, absolute viscosity, $m/\ell t$
V, velocity, ℓ/t
ℓ, characteristic length, ℓ
Two phase flow in porous media
Ref. 21

CAPILLARITY 2

$$\left(\frac{\mu a}{\sigma}\right)^2$$

μ, absolute viscosity, $m/\ell t$
a, sonic speed, ℓ/t
σ, surface tension, m/t^2
Action of surface tension in flowing media
A material property
Similar to Capillary
Ref. 30

CAPILLARITY-BUOYANCY

$$\frac{g\mu^4}{\rho\sigma^3}$$

g, gravitational acceleration, ℓ/t^2
μ, absolute viscosity, $m/\ell t$
ρ, mass density, m/ℓ^3
σ, surface tension, m/t^2
Effects of surface tension and acceleration on two phase flow
Ref. 30

CAPILLARY

$$\frac{\text{Viscous force}}{\text{Surface tension force}}$$

$$\frac{\mu V}{\sigma}$$

μ, absolute viscosity, $m/\ell t$
V, velocity, ℓ/t
σ, surface tension, m/t^2
Liquid flow in particulate beds
Similar to Capillarity 2
Ref. 29, definition only

CARNOT

$$\frac{T_2 - T_1}{T_2}$$

T_2, source temperature, T
T_1, sink temperature, T
Carnot cycle thermal efficiency
Ref. 30

CAUCHY

$$\frac{\text{Inertia force}}{\text{Elastic force}}$$

$$\frac{V^2}{a^2}$$

V, speed, ℓ/t
a, sonic speed, ℓ/t
Compressible flow, equal to (Mach)^2
Ref. 2

CAVITATION

$$\frac{\text{Pressure margin}}{\text{Dynamic pressure}}$$

$$\frac{p - p_c}{q}$$

p, local static pressure, $m/\ell t^2$
p_c, fluid vapor pressure, $m/\ell t^2$
q, dynamic pressure, $\rho V^2/2$, $m/\ell t^2$
ρ, mass density, m/ℓ^3
V, velocity, ℓ/t
Hydrofoils, nozzles, pumps, see Thoma
Ref. 2

CENTRIFUGE

$$\frac{\text{Centrifugal force}}{\text{Capillary force}}$$

$$\frac{\rho R^2 h \omega^2}{\sigma}$$

ρ, mass density, m/ℓ^3
R, tank radius, ℓ
h, liquid depth, ℓ
ω, angular velocity, $1/t$
σ, surface tension, m/t^2
Slosh
Ref. 4

CLAUSIUS

$$\frac{V^3 \ell \rho}{k \Delta T}$$

V, velocity, ℓ/t
ℓ, characteristic dimension, ℓ
ρ, mass density, m/ℓ^3
k, thermal conductivity, $m\ell/t^3T$
ΔT, temperature difference, T
Heat conduction in forced flow
Ref. 30

COLBURN

$$\frac{\text{Momentum diffusivity}}{\text{Mass diffusivity}}$$

$$\frac{\mu}{\rho D}$$

μ, absolute viscosity, $m/\ell t$
ρ, mass density, m/ℓ^3
D, mass diffusivity, ℓ^2/t
A material property, equals Prandtl/Lewis, Schmidt
Diffusion in flowing systems
Refs. 16, 13

CONDENSATION 1

$$\frac{h}{k}\left(\frac{\mu^2}{\rho^2 g}\right)^{1/3}$$

h, heat transfer coefficient, m/t^3T
k, heat conductivity, $m\ell/t^3T$
μ, absolute viscosity, $m/\ell t$
ρ, mass density, m/ℓ^3
g, gravitational acceleration, ℓ/t^2
Ref. 29, definition only

CONDENSATION 2

$$\frac{\ell^3\rho^2 g\lambda}{k\mu\ \Delta T}$$

ℓ, characteristic length, ℓ
ρ, mass density, m/ℓ^3
g, gravitational acceleration, ℓ/t^2
λ, latent heat of condensation, heat/mass, ℓ^2/t^2
k, heat conductivity, $m\ell/t^3T$
μ, absolute viscosity, $m\ell/t$
ΔT, temperature difference across liquid film, T
Vertical wall condensation
Ref. 29, definition only

COWLING

$$\frac{\text{Velocity of Alfvén wave}}{\text{Velocity of fluid}}$$

$$\frac{B}{V(\rho\mu)^{1/2}}$$

V, flow speed, ℓ/t
ρ, mass density, m/ℓ^3
μ, magnetic permeability, $m\ell/Q^2$
B, magnetic induction, m/Qt
Magnetohydrodynamics
Equals 1/Magnetic Mach, 1/Alfvén
Ref. 29, definition only

CRISPATION

$$\frac{\mu D}{\sigma d}$$

μ, absolute viscosity, $m/\ell t$
D, thermal diffusivity, ℓ^2/t
σ, surface tension, m/t^2
d, fluid depth, ℓ
Cellular convection
Ref. 26

CROCCO

$$\frac{\text{Velocity}}{\text{Maximum velocity}}$$

$$\frac{V}{V_{max}}$$

V, velocity, ℓ/t
V_{max}, maximum velocity of gas when expanded to zero temperature, ℓ/t

$$\frac{V}{V_{max}} = \left[1 + \frac{2}{(\gamma - 1)M^2}\right]^{1/2}$$

γ, specific heat ratio, 1
M, Mach number, 1

Compressible flow
Equals Laval
Ref. 29, definition only

DAMKÖHLER'S FIRST

$$\frac{\text{Reaction rate}}{\text{Flow rate}}$$

$$\frac{U\ell}{Vc}$$

U, reaction rate, $m/\ell^3 t$
ℓ, characteristic length, ℓ
V, velocity, ℓ/t
c, concentration, m/ℓ^3

or

$$\frac{\text{Translation time}}{\text{Reaction (or relaxation) time}}$$

$$\frac{t_t}{t_r}$$

t_t, translation time, t
t_r, reaction time, t
Flowing and reacting fluids, real gases
Similar to Deborah
Refs. 7, 30

DAMKOHLER'S SECOND

$$\frac{\text{Reaction rate}}{\text{Diffusion rate}}$$

$$\frac{U\ell^2}{Dc}$$

U, reaction rate, $m/\ell^3 t$
ℓ, characteristic length, ℓ
D, mass diffusivity, ℓ^2/t
c, concentration, m/ℓ^3
Chemical reactions with mass transfer
Ref. 7, 30

DAMKÖHLER'S THIRD

$$\frac{\text{Heat liberated}}{\text{Heat transported}}$$

$$\frac{QU\ell}{c_p\rho VT}$$

Q, heat liberated/mass, ℓ^2/t^2
U, reaction rate, $m/\ell^3 t$
ℓ, characteristic length, ℓ
c_p, specific heat at constant pressure, $\ell^2/t^2 T$
V, velocity, ℓ/t
ρ, mass density, m/ℓ^3
T, temperature, T
Chemical reaction and heat transfer
Ref. 7, 30

DAMKÖHLER'S FOURTH

$$\frac{\text{Heat liberated}}{\text{Heat conducted}}$$

$$\frac{QU\ell^2}{kT}$$

Q, heat liberated/mass, ℓ^2/t^2
U, reaction rate, $m/\ell^3 t$
ℓ, characteristic length, ℓ
k, heat conductivity, $m\ell/t^2T$
T, temperature, T
Chemical reaction and heat transfer
Ref. 7, 30

DAMKÖHLER'S FIFTH

$$\frac{\text{Inertia force}}{\text{Viscous force}}$$

$$\frac{\rho V\ell}{\mu}$$

ρ, mass density, m/ℓ^3
V, velocity, ℓ/t
ℓ, characteristic length, ℓ
μ, absolute viscosity, $m/\ell t$
Flow of real fluids
Same as Reynolds
Ref. 1

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DARCY

$$\frac{\text{Head loss}}{\text{Velocity head}} \times \frac{\text{Diameter}}{\text{Length}}$$

$$\frac{2ghd}{V^2\ell}$$

g, gravitational acceleration, ℓ/t^2
h, loss in head, ℓ
d, diameter, ℓ
V, velocity, ℓ/t
ℓ, length, ℓ
Pipe flow
See Fanning
Ref. 29, definition only

DEAN

$$\frac{\rho V \ell}{\mu}\left(\frac{\ell}{2r}\right)^{1/2}$$

or

$$\left(\frac{\ell}{2r}\right)^{1/2} \times \text{Reynolds}$$

ρ, mass density, m/ℓ^3
V, velocity, ℓ/t
μ, absolute viscosity, $m/\ell t$
ℓ, channel width or pipe diameter, ℓ
r, radius of bend curvature, ℓ
Curved channel flow
Ref. 30

DEBORAH

$$\frac{\text{Relaxation time}}{\text{Observation time}}$$

Flow of thixotropic and viscoelastic materials
Similar to Damköhler's First
Ref. 27

DEBYE

$$\frac{\text{Debye length}}{\text{Probe radius}}$$

$$\frac{\lambda_D}{a}$$

a, probe radius, ℓ
λ_D, Debye length, $\left(\frac{k\epsilon T}{e^2 n}\right)^{1/2}$

k, Boltzmann constant, $m\ell^2/t^2T$
ϵ, permittivity of free space, $Q^2t^2/m\ell^3$
e, electron charge, Q
n, number of electrons/volume, $1/\ell^3$

Electrostatic probing in ionized gases
Ref. 24

DERYAGIN

$$\frac{\text{Film thickness}}{\text{Capillary length}}$$

$$\ell\left(\frac{\rho g}{2\sigma}\right)^{1/2}$$

ℓ, film thickness, ℓ
ρ, mass density, m/ℓ^3
g, gravitational acceleration, ℓ/t^2
σ, surface tension, m/t^2
Coating
See Goucher, Bond, Eötvös
Ref. 30

DULONG

$$\frac{\text{Kinetic energy}}{\text{Thermal energy}}$$

$$\frac{V^2}{c_p(T_2-T_1)}$$

V, speed, ℓ/t
c_p, specific heat at constant pressure, ℓ^2/t^2T
T_2-T_1, temperature range of interest, T
Compressible flow
Equals Eckert
Ref. 30

ECKERT

$$\frac{\text{Kinetic energy}}{\text{Thermal energy}}$$

$$\frac{V^2}{c_p \Delta T}$$

V, velocity, ℓ/t
c_p, specific heat at constant pressure, ℓ^2/t^2T
ΔT, temperature range of interest, T
Compressible flow
Equals Dulong
Ref. 10, 16

EINSTEIN

$$\frac{\text{Fluid velocity}}{\text{Velocity of light}}$$

Magnetohydrodynamics
Equals Lorentz
Ref. 29, definition only

EKMAN

$$\frac{\text{Viscous force}}{\text{Centrifugal force}}$$

$$\frac{\nu}{2\omega\ell^2}$$

or

$$\left(\frac{\mu}{2\rho\omega\ell^2}\right)^{1/2}$$

ν, kinematic viscosity, ℓ^2/t
ω, angular velocity, $1/t$
ℓ, characteristic length, ℓ
μ, absolute viscosity, $m/\ell t$
ρ, mass density, m/ℓ^3
Fluid in spinning tank
Magnetohydrodynamics
Ref. 15, 30

ELASTICITY 1

$$\frac{\text{Elastic force}}{\text{Inertia force}}$$

$$\frac{t_r \mu}{\rho r^2}$$

t_r, relaxation time, t
μ, absolute viscosity, $m/\ell t$
ρ, mass density, m/ℓ^3
r, pipe radius, ℓ

or

$$\frac{\lambda \mu_0}{\rho D^2}$$

μ_0, zero shear viscosity, $m/\ell t$
ρ, mass density, m/ℓ^3
D, jet diameter, ℓ
λ, time constant, t from:
$\tau + \lambda \dot{\tau} = -\mu_0 \Delta$
τ, shear stress, $m/\ell t^2$
$\dot{\tau}$, shear stress rate, $m/\ell t^3$
Δ, deformation rate, $1/t$
Viscoelastic flow
Ref. 18, 30

ELASTICITY 2

$$\frac{c_p}{\beta a^2}$$

c_p, specific heat at constant pressure, ℓ^2/t^2T
β, coefficient of volume expansion, $1/T$
a, sonic speed, ℓ/t
A material property
Effect of elasticity in flow processes
See Elasticity 3
Ref. 30

ELASTICITY 3

$$\frac{\rho c_p}{\beta E}$$

ρ, mass density, m/ℓ^3
c_p, specific heat at constant pressure, ℓ^2/t^2T
β, coefficient of bulk expansion, $1/T$
E, modulus of elasticity, $m/\ell t^2$
Effect of elasticity on flow
A fluid property
See Elasticity 2
Ref. 30

ELECTRIC REYNOLDS

$$\frac{\epsilon V}{qb\ell}$$

ϵ, permittivity, $Q^2t^2/m\ell^3$
V, velocity, ℓ/t
q, space charge density, Q/ℓ^3
b, carrier mobility, speed/voltage gradient, Qt/m
Magnetohydrodynamics
Ref. 29 definition only

ELECTROVISCOUS

$$\left(\frac{\rho_p}{2\pi\epsilon}\right)^{1/2} \frac{\ell^2}{\nu} \frac{q}{m_p}$$

ρ_p, mass density of particle cloud, m/ℓ^3
ϵ, permittivity of free space, $Q^2t^2/m\ell^3$
ℓ, characteristic length, ℓ
ν, kinematic viscosity of gas, ℓ^2/t
q, charge, Q
m_p, particle mass, m
Charged particles in flowing gas
Electrostatic precipitators
Ref. 33

ELLIS

$$\frac{\mu_0 V}{2\tau_{1/2} R}$$

μ_0, zero shear viscosity, $m/\ell t$
V, velocity, ℓ/t
$\tau_{1/2}$, shear stress when $\mu = \mu_0/2$, $m/\ell t^2$
R, tube radius, ℓ
Non-Newtonian flow
Ref. 30

ELSASSER

$$\frac{\rho}{\mu \sigma \mu_m}$$

ρ, mass density, m/ℓ^3
μ, absolute viscosity, $m/\ell t$
σ, electrical conductivity, $Q^2 t/m\ell^3$
μ_m, magnetic permeability, $m\ell/Q^2$
Magnetohydrodynamics
Ref. 30

EÖTVÖS

$$\frac{\text{Gravity force}}{\text{Surface tension force}}$$

$$\frac{\rho \ell^2 g}{\sigma}$$

ρ, mass density, m/ℓ^3
ℓ, characteristic length, ℓ
g, gravitational acceleration, ℓ/t^2
σ, surface tension, m/t^2
Capillary flow, sloshing
Equals Bond
Equals Weber/Froude
Ref. 30

EULER

$$\frac{\text{Pressure force}}{\text{Inertia force}}$$

$$\frac{p}{\rho V^2}$$

p, local static pressure (or pressure drop), $m/\ell t^2$
ρ, mass density, m/ℓ^3
V, velocity, ℓ/t
Pressure distributions
Equals Newton
See Fanning
Ref. 1, 16

EVAPORATION 1

$$\frac{V^2}{H_v}$$

V, velocity, ℓ/t
H_v, heat of vaporization/mass, ℓ^2/t^2
Evaporation processes
Ref. 30

EVAPORATION 2

$$\frac{c_p}{H_v\beta}$$

c_p, specific heat at constant pressure, ℓ^2/t^2T
H_v, heat of vaporization/mass, ℓ^2/t^2
β, coefficient of volume expansion, $1/T$
Evaporation processes
Ref. 30

EVAPORATION-ELASTICITY

$$\frac{a^2}{H_v}$$

a, sonic speed, ℓ/t
H_v, heat of vaporization/mass, ℓ^2/t^2
Evaporation processes
Ref. 30

EXPLOSION

$$\frac{r}{\left(\frac{E}{\rho}\right)^{1/5} t^{2/5}}$$

r, blast wave radius, ℓ
E, explosive energy, $m\ell^2/t^2$
ρ, mass density of medium, m/ℓ^3
t, time, t
Blast wave growth from instantaneous energy release
Ref. 2

FANNING

$$\frac{\text{Shear stress}}{\text{Dynamic pressure}}$$

$$\frac{2\tau}{\rho V^2}$$

τ, shear (friction) stress, $m/\ell t^2$
ρ, mass density, m/ℓ^3
V, velocity, ℓ/t
Friction flow
See Euler, Newton
Ref. 13, 16

FEDEROV

$$d\left[\frac{4g\rho^2}{3\mu^2}\left(\frac{\lambda M}{\lambda g}-1\right)\right]^{1/3}$$

d, particle diameter, ℓ
g, gravitational acceleration, ℓ/t^2
ρ, mass density of fluid, m/ℓ^3
μ, absolute viscosity of fluid, $m/\ell t$
λM, specific gravity of particles, 1
λg, specific gravity of fluid, 1
Fluidized beds
Similar to Archimedes
Ref. 30

FLIEGNER

$$\frac{Q_m(c_pT)^{1/2}}{A(p+\rho V^2)}$$

Q_m, mass flow rate, m/t
c_p, specific heat at constant pressure, ℓ^2/t^2T
T, absolute temperature, T
A, flow area, ℓ^2
p, static pressure, $m/\ell t^2$
ρ, mass density, m/ℓ^3
V, velocity, ℓ/t
Compressible flow
Ref. 30

FLOW

$$\frac{Q_v}{ND^3}$$

Q_v, volume flow rate, ℓ^3/t
N, rotational speed, $1/t$
D, impeller diameter, ℓ
Fans, turbines, etc.
Ref. 30

FOURIER (heat transfer)

$$\frac{kt}{c_p \rho \ell^2}$$

k, heat conductivity, $m\ell/t^3T$
t, time, t
c_p, specific heat at constant pressure, ℓ^2/t^2T
ρ, mass density, m/ℓ^3
ℓ, characteristic length, ℓ
Unsteady state heat transfer
Ref. 30

FOURIER (mass transfer)

$$\frac{Dt}{\ell^2}$$

D, mass diffusivity, ℓ^2/t
t, time, t
ℓ, characteristic length, ℓ
Unsteady state mass transfer
Ref. 30

FROUDE

$$\frac{\text{Inertia force}}{\text{Gravity force}}$$

$$\frac{V^2}{g\ell}$$

sometimes:

$$\frac{V}{\sqrt{g\ell}}$$

V, velocity, ℓ/t
g, gravitational acceleration, ℓ/t^2
ℓ, characteristic length, ℓ
Surface wave motion
Surface ships
Gravity-affected motions
Ref. 1

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FRUEH

$$\frac{b\omega_\alpha}{a}\left(\frac{\mu}{C_{L_\alpha}}\right)^{1/2}$$

b, wing half chord, ℓ
ω_α, first torsional natural frequency of wing, $1/t$
a, sonic speed, ℓ/t
C_{L_α}, wing lift curve slope, 1
μ, mass ratio, 1

$$\mu = \frac{m}{\rho b^2}$$

m, wing mass/length, m/ℓ
ρ, mass density of air, m/ℓ^3

Transonic wing flutter
Ref. 27

GALILEO

$$\frac{\text{Gravity force}}{\text{Viscous force}}$$

$$\frac{g\ell^3}{\nu^2}$$

g, gravitational acceleration, ℓ/t^2
ℓ, characteristic length, ℓ
ν, kinematic viscosity, ℓ^2/t
Slosh of liquids, free flow
Ref. 1

GOUCHER

$$\frac{\text{Gravity force}}{\text{Surface tension force}}$$

$$R\left(\frac{\rho g}{2\sigma}\right)^{1/2}$$

R, wire radius, ℓ
ρ, mass density, m/ℓ^3
g, gravitational acceleration, ℓ/t^2
σ, surface tension, m/t^2
Coating
See Deryagin, Bond, Eötvös
Ref. 30

GRAETZ

$$\frac{\text{Thermal capacity of fluid}}{\text{Conductive heat transfer}}$$

$$\frac{Q_m c_p}{k\ell}$$

Q_m, mass flow rate, m/t
c_p, specific heat at constant pressure, ℓ^2/t^2T
k, heat conductivity, $m\ell/t^3T$
ℓ, characteristic length, ℓ
Conductive heat transfer in streamline flow
Ref. 3

GRASHOF

$$\frac{\text{Inertia force} \times \text{Buoyant force}}{(\text{Viscous force})^2}$$

$$\frac{\rho^2 g \ell^3 \beta \Delta T}{\mu^2}$$

ρ, mass density, m/ℓ^3
g, gravitational acceleration, ℓ/t^2
ℓ, characteristic length, ℓ
β, temperature coefficient of volume expansion, $1/T$
ΔT, temperature difference, T
μ, absolute viscosity, $m/\ell t$
Free convection
Ref. 3

GRAVITY

$$\frac{\text{Gravity force}}{\text{Filtration force}}$$

$$\frac{kg\,\Delta\rho}{\mu V}$$

k, permeability, ℓ^2
g, gravitational acceleration, ℓ/t^2
$\Delta\rho$, mass density difference between fluids, m/ℓ^3
μ, absolute viscosity of reference fluid, $m/\ell t$
V, reference velocity, ℓ/t
Two-phase flow in porous media
Ref. 21

GUKHMAN

$$\frac{T_g - T_s}{T_g}$$

T_g, temperature of ambient gas, T
T_s, wet bulb temperature at moist surface, T
Evaporation from moist surface
Ref. 10

HALL

$$\omega\tau$$

ω, cyclotron frequency, $1/t$
τ, average free path/average velocity, t
Magnetohydrodynamics
Ref. 30

HARTMANN

$$\frac{\text{Magnetic force}}{\text{Viscous force}}$$

$$\frac{B\sigma^{1/2}\ell}{\mu^{1/2}}$$

B, magnetic induction, m/Qt
σ, electrical conductivity, $Q^2t/m\ell^3$
ℓ, characteristic length, ℓ
μ, absolute viscosity, $m/\ell t$
Magnetohydrodynamics
Ref. 30

HEAT TRANSFER

$$\frac{\dot{H}}{\rho V^3 \ell^2}$$

$\dot{H}$, heat flow/time, $m\ell^2/t^3$
ρ, mass density, m/ℓ^3
V, velocity, ℓ/t
ℓ, characteristic length, ℓ
Heat transfer in stream
Ref. 30

HEDSTROM 1

$$\frac{\sigma_0 \rho \ell^2}{\mu_p^2}$$

σ_0, stress at elastic yield, $m/\ell t^2$
ρ, mass density, m/ℓ^3
ℓ, characteristic length, ℓ
μ_p, absolute viscosity in plastic state, $m/\ell t$
Flow of Bingham type plastics
Equals Reynolds × Bingham
Ref. 11

HEDSTROM 2

$$\frac{\sigma_0 \ell}{\mu_p V}$$

σ_0, stress at elastic yield, $m/\ell t^2$
ℓ, characteristic length, ℓ
μ_p, absolute viscosity in plastic state, $m/\ell t$
V, average velocity, ℓ/t
Flow of Bingham type plastics
Equal to Bingham
Ref. 11

HERSEY

$$\frac{\text{Load force}}{\text{Viscous force}}$$

$$\frac{F}{\mu V \ell}$$

F, load on bearing, $m\ell/t^2$
μ, absolute viscosity, $m/\ell t$
V, bearing surface speed, ℓ/t
ℓ, bearing length, ℓ
Bearing lubrication
See Ocvirk, Sommerfeld
Ref. 30

HODGSON

$$\frac{\text{Time constant of system}}{\text{Period of pulsation}}$$

$$\frac{Vf\Delta p}{Q_v p}$$

V, volume of system, ℓ^3
f, pulsation frequency, $1/t$
Δp, pressure drop, $m/\ell t^2$
Q_v, volume flow rate, ℓ^3/t
p, average static pressure, $m/\ell t^2$
Pulsating flow
Ref. 29 definition only

HOOKE

$$\frac{\text{Inertia force}}{\text{Elastic force}}$$

$$\frac{V^2}{a^2}$$

V, speed, ℓ/t
a, sonic speed, ℓ/t
Compressible flow
Equals (Mach)^2
Equals Cauchy
Ref. 30

J FACTOR (heat transfer)

$$\frac{h}{c_p G}\left(\frac{c_p \mu}{k}\right)^{2/3}$$

h, heat transfer coefficient, m/t^3T
c_p, specific heat at constant pressure, ℓ^2/t^2T
G, mass transfer, mass/area × time, $m/\ell^2 t$
μ, absolute viscosity, $m/\ell t$
k, heat conductivity, $m\ell/t^3T$
Heat and mass transfer
Ref. 30

J FACTOR (mass transfer)

$$\frac{k_c \rho}{G}\left(\frac{\mu}{\rho D}\right)^{2/3}$$

k_c, mass transfer coefficient, ℓ/t
ρ, mass density, m/ℓ^3
G, mass transfer, mass/area × time, $m/\ell^2 t$
μ, absolute viscosity, $m/\ell t$
D, mass diffusivity, ℓ^2/t
Mass transfer
Ref. 30

JACOB

$$\frac{h}{c_p \Delta T}$$

h, heat of evaporation, ℓ^2/t^2
c_p, specific heat at constant pressure, ℓ^2/t^2T
ΔT, temperature differential, T
Ref. 16

JAKOB

$$\frac{(T_0 - T_{sat})\ \rho_l c_p}{\lambda \rho_v}$$

T_0, bulk liquid temperature, T
T_{sat}, saturation temperature, T
c_p, specific heat at constant pressure, ℓ^2/t^2T
ρ_l, mass density of liquid, m/ℓ^3
ρ_v, mass density of vapor, m/ℓ^3
λ, latent heat of vaporization, ℓ^2/t^2
Boiling
Ref. 10

JEFFREY

$$\frac{\text{Gravity force}}{\text{Viscous force}}$$

$$\frac{\rho g \ell^2}{\mu V}$$

ρ, mass density, m/ℓ^3
g, gravitational acceleration, ℓ/t^2
ℓ, characteristic length, ℓ
μ, absolute viscosity, $m/\ell t$
V, velocity, ℓ/t
Slow flow
Equals Reynolds/Froude
Equals 1/Stokes
Ref. 17

JOULE

$$\frac{\text{Joule heating energy}}{\text{Magnetic field energy}}$$

$$\frac{2\rho c_p \Delta T}{\mu H^2}$$

ρ, mass density, m/ℓ^3
c_p, specific heat at constant pressure, ℓ^2/t^2T
ΔT, temperature difference, T
μ, magnetic permeability, $m\ell/Q^2$
H, magnetizing force, $Q/\ell t$
Magnetohydrodynamics
Ref. 30

KÁRMÁN 1

$$\frac{\rho p d^3}{\mu^2 \ell}$$

ρ, mass density, m/ℓ^3
p, pressure drop, $m/\ell t^2$
d, pipe diameter, ℓ
μ, absolute viscosity, $m/\ell t$
ℓ, characteristic length, ℓ
Pipe flow with friction
Ref. 29 definition only

KÁRMÁN 2

$$\frac{\text{Flow speed}}{\text{Alfvén wave speed}}$$

$$\frac{V(\rho\mu)^{1/2}}{\beta}$$

V, flow speed, ℓ/t
ρ, mass density, m/ℓ^3
μ, magnetic permeability, $m\ell/Q^2$
β, magnetic induction, m/Qt
Magnetohydrodynamics
Equals Alfvén, Magnetic Mach
Ref. 30

KIRPICHEV (heat transfer)

$$\frac{\text{External heat transfer intensity}}{\text{Internal heat transfer intensity}}$$

$$\frac{\dot{H}\ell}{k\Delta T}$$

$\dot{H}$, specific heat flow, heat/area time, m/t^3
ℓ, characteristic length, ℓ
k, heat conductivity, $m\ell/t^3T$
ΔT, temperature differential, T
Heat transfer
See Nusselt
Ref. 10

KIRPICHEV (mass transfer)

$$\frac{\text{External mass transfer intensity}}{\text{Internal mass transfer intensity}}$$

$$\frac{G\ell}{D\rho\Delta\mu}$$

G, mass of moisture evaporated/area time, m/ℓ^2t
ℓ, characteristic length, ℓ
D, mass diffusivity of moisture in body, ℓ^2/t
ρ, mass density, m/ℓ^3
$\Delta\mu$, change in moisture in body, m/m, 1
Moisture evaporation from porous bodies
Ref. 10

KIRPITCHEFF

$$\left(\frac{\rho F}{\mu^2}\right)^{1/3}$$

ρ, mass density of fluid, m/ℓ^3
F, resistance force on immersed body, $m\ell/t^2$
μ, absolute viscosity of fluid, $m/\ell t$
Flow over immersed bodies
Ref. 30

KNUDSEN

$$\frac{\text{Molecular mean free path}}{\text{Characteristic body length}}$$

$$\frac{L}{\ell}$$

L, mean free path of molecules, ℓ
ℓ, characteristic body length, ℓ
Rarefied gas flow
Equals $K \times$ Mach/Reynolds, where $K = 1.28\ \sqrt{c_p/c_v}$
Ref. 2

KOSSOVICH

$$\frac{\text{Heat to evaporate moisture}}{\text{Heat to raise body temperature}}$$

$$\frac{H_e \Delta u}{c \Delta T}$$

H_e, specific heat of evaporation of liquid, ℓ^2/t^2
Δu, change in moisture content of body, m/m, 1
c, specific heat of body, ℓ^2/t^2T
ΔT, body temperature change, T
Evaporation of moisture from porous bodies
Ref. 10

LAGRANGE 1

$$\frac{\text{Pressure force}}{\text{Viscous force}}$$

$$\frac{\Delta p \ell}{\mu V}$$

Δp, pressure drop, $m/\ell t^2$
ℓ, characteristic length, ℓ
μ, absolute viscosity, $m/\ell t$
V, velocity, ℓ/t
Laminar flow
Equals Euler × Reynolds
Ref. 1

LAGRANGE 2

$$\frac{P}{\mu \ell^3 \omega^2}$$

P, power input to agitator, $m\ell^2/t^3$
μ, absolute viscosity, $m/\ell t$
ℓ, characteristic length, ℓ
ω, rotational speed of agitator $1/t$
Rotating agitators
Ref. 29 definition only

LAVAL

$$\frac{V}{V_m}$$

V, flow velocity, ℓ/t
V_m, maximum velocity—obtained when flow is expanded to zero absolute temperature:

$$V_m = \left(\frac{2\gamma}{\gamma - 1} RT_t\right)^{1/2}$$

γ, specific heat ratio, c_p/c_v, 1
R, gas constant, ℓ^2/t^2T
T_t, total (stagnation) temperature, T
Compressible flow
Equals Crocco
Ref. 30

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LEROUX

$$\frac{2(p-p_c)}{\rho V^2}$$

p, local static pressure, $m/\ell t^2$
p_c, fluid vapor pressure, $m/\ell t^2$
ρ, mass density, m/ℓ^3
V, velocity, ℓ/t
Cavitation
Equals Cavitation Number
Ref. 29 definition only

LEVERETT

$$\frac{\text{Characteristic dimension of interfacial curvature}}{\text{Characteristic dimension of pores}}$$

$$\left(\frac{k}{p}\right)^{1/2}\frac{p_c}{\sigma}$$

k, permeability, ℓ^2
p, porosity, volume of voids/total volume, 1
p_c, capillary pressure, $m/\ell t^2$
σ, surface tension, m/t^2
Two phase flow in porous media
Ref. 30

LEWIS

$$\frac{\text{Mass diffusivity}}{\text{Thermal diffusivity}}$$

$$\frac{D\rho c_p}{k}$$

D, mass diffusivity, ℓ^2/t
ρ, mass density, m/ℓ^3
c_p, specific heat at constant pressure, ℓ^2/t^2T
k, heat conductivity, $m\ell/t^3T$
Combined heat and mass transfer
A fluid property
Equals Prandtl/Schmidt
Equals Semenov
Sometimes given as reciprocal of above
Ref. 10, 13, 16

LORENTZ

$$\frac{\text{Fluid velocity}}{\text{Velocity of light}}$$

Magnetohydrodynamics
Equals Einstein
Ref. 30

LUIKOV

$$\frac{\text{Moisture diffusivity in porous body}}{\text{Thermal diffusivity in porous body}}$$

Moist, porous bodies
Ref. 10

LUNDQUIST

$$\frac{\sigma H \ell \mu^{3/2}}{\rho^{1/2}}$$

σ, electrical conductivity, $Q^2 t / m \ell^3$
H, magnetizing force, $Q / \ell t$
ℓ, fluid layer thickness, ℓ
μ, magnetic permeability, $m \ell / Q^2$
ρ, mass density, m / ℓ^3
Magnetohydrodynamics
Ref. 30

LYKOUDIS

$$\frac{\sigma}{\rho}(\mu H)^2\left(\frac{\ell}{g\beta\Delta T}\right)^{1/2}$$

μ, magnetic permeability, $m\ell/Q^2$
H, magnetizing force, $Q/\ell t$
σ, electrical conductivity, $Q^2t/m\ell^3$
ρ, mass density, m/ℓ^3
ℓ, characteristic length, ℓ
g, gravitational acceleration, ℓ/t^2
β, temperature coefficient of volume expansion, $1/T$
ΔT, temperature differential, T
Magnetohydrodynamics
Ref. 30

MACH

$$\frac{\text{Inertia force}}{\text{Elastic force}}$$

$$\frac{V}{a}$$

V, velocity, ℓ/t
a, sonic velocity, ℓ/t
Compressible gas flow
Equals (Cauchy)$^{1/2}$
Ref. 1

MAGNETIC-DYNAMIC

$$\frac{\text{Magnetic pressure}}{\text{Dynamic pressure}}$$

$$\frac{\sigma V B^2 \ell}{\rho V^2}$$

σ, electrical conductivity, $Q^2t/m\ell^3$
V, velocity, ℓ/t
B, magnetic induction, m/Qt
ℓ, characteristic length, ℓ
ρ, mass density, m/ℓ^3
Magnetohydrodynamics
See Magnetic Pressure
Ref. 2

MAGNETIC FORCE

$$\frac{\text{Magnetic force}}{\text{Inertia force}}$$

$$\frac{\mu^2 H^2 \sigma \ell}{\rho V}$$

μ, magnetic permeability, $m\ell/Q^2$
H, magnetizing force, $Q/\ell t$
σ, electrical conductivity, $Q^2t/m\ell^3$
ρ, mass density, m/ℓ^3
V, velocity, ℓ/t
ℓ, characteristic field dimension, ℓ
Magnetohydrodynamics
See Magnetic Pressure
Ref. 30

MAGNETIC INTERACTION

$$\frac{\mu H^2 R}{2\sigma}$$

μ, free space permeability, $m\ell/Q^2$
H, magnetizing force, $Q/\ell t$
R, tank radius, ℓ
σ, surface tension, m/t^2
Dynamics of ferro fluids
Ref. 28

MAGNETIC MACH

$$\frac{\text{Flow speed}}{\text{Alfvén wave speed}}$$

$$\frac{V(\rho\mu)^{1/2}}{B}$$

V, flow velocity, ℓ/t
ρ, mass density, m/ℓ^3
μ, magnetic permeability, $m\ell/Q^2$
B, magnetic induction, m/Qt
Magnetohydrodynamics
Equals Alfvén, 1/Cowling
Ref. 2

MAGNETIC PRANDTL

$$\mu\sigma\nu$$

μ, magnetic permeability, $m\ell/Q^2$
σ, electrical conductivity, $Q^2t/m\ell^3$
ν, kinematic viscosity, ℓ^2/t
Magnetohydrodynamics
Ref. 29 definition only

MAGNETIC PRESSURE

$$\frac{\text{Magnetic pressure}}{\text{Dynamic pressure}}$$

$$\frac{\mu H^2}{\rho V^2}$$

μ, magnetic permeability, $m\ell/Q^2$
H, magnetizing force, $Q/\ell t$
ρ, mass density, m/ℓ^3
V, velocity, ℓ/t
Magnetohydrodynamics
See Magnetic Dynamic
Ref. 30

MAGNETIC REYNOLDS

$$\frac{\text{Motion induced magnetic field}}{\text{Applied magnetic field}}$$

$$\sigma V \ell \mu$$

σ, electrical conductivity, $Q^2t/m\ell^3$
V, velocity, ℓ/t
ℓ, characteristic length, ℓ
μ, magnetic permeability, $m\ell/Q^2$
Magnetohydrodynamics
Ref. 2

MARANGONI

$$\frac{\Delta\sigma}{\Delta T}\frac{\Delta T}{\Delta \ell}\frac{d^2}{\mu D}$$

$\Delta\sigma/\Delta T$, surface tension-temperature coefficient, m/t^2T
$\Delta T/\Delta\ell$, temperature-length gradient, T/ℓ
d, fluid depth, ℓ
μ, absolute viscosity, $m/\ell t$
D, thermal diffusivity, ℓ^2/t
Cellular convection due to surface tension gradients
Ref. 26

MASS RATIO

$$\frac{\text{Mass of immersed body}}{\text{Mass of surrounding fluid}}$$

$$\frac{m}{\pi\rho\ell^3}$$

m, mass of body, m
ρ, mass density of fluid, m/ℓ^3
ℓ, characteristic body length, ℓ
Airplane flutter and stability
Ref. 8

McADAMS

$$\frac{h^4\ell\,\mu\Delta T}{k^3\rho^2 gH}$$

h, heat transfer coefficient, m/t^3T
ℓ, characteristic dimension, ℓ
μ, absolute viscosity, $m/\ell\,t$
ΔT, temperature difference, T
k, heat conductivity, $m\ell/t^3T$
ρ, mass density, m/ℓ^3
g, gravitational acceleration, ℓ/t^2
H, latent heat of condensation, ℓ^2/t^2
Condensation
Ref. 30

MERKEL

$$\frac{\text{Mass of water transferred/unit humidity difference}}{\text{Mass of dry gas}}$$

$$\frac{MAW}{V_m}$$

M, mass transfer rate, mass/area time, $m/\ell^2 t$
A, cooling surface area/volume, $1/\ell$
W, total volume, ℓ^3
V_m, mass flow rate of gas, m/t
Cooling towers
Ref. 30

MOMENTUM

$$\frac{M\ell}{\nu \Delta V}$$

M, momentum flux, ℓ^2/t^2
ℓ, thickness of layer, ℓ
ν, kinematic viscosity, ℓ^2/t
ΔV, velocity difference, ℓ/t
Convection in ocean and atmosphere
Ref. 22

MORTON

$$\frac{g\mu^4}{\rho\sigma^3}$$

g, gravitational acceleration, ℓ/t^2
μ, absolute viscosity, $m/\ell t$
ρ, mass density, m/ℓ^3
σ, surface tension, m/t^2
Bubble movement
Ref. 19

NAZE

$$\frac{\text{Alfvén wave speed}}{\text{Sonic speed}}$$

Magnetohydrodynamics
Ref. 30

NEWTON

$$\frac{F}{\rho V^2 \ell^2}$$

F, force on immersed body, $m\ell/t^2$
ρ, mass density of fluid, m/ℓ^3
ℓ, characteristic length, ℓ
V, velocity, ℓ/t
Forces on immersed bodies
Ref. 13

NO NAME 1

$$\frac{\text{Weight}}{\text{Stiffness}}$$

$$\frac{\sigma \ell}{E}$$

σ, weight density, $m/\ell^2 t^2$
ℓ, characteristic length, ℓ
E, modulus of elasticity, $m/\ell t^2$
Structural merit
Ref. 8

NO NAME 2

$$\frac{\text{Stiffness}}{\text{Aerodynamic force}}$$

$$\frac{2E}{\rho V^2}$$

E, modulus of elasticity, $m/\ell t^2$
ρ, mass density, m/ℓ^3
V, velocity, ℓ/t
Aeroelasticity
Ref. 8

NO NAME 3

$$\frac{\text{Viscous pressure}}{\text{Capillary pressure}}$$

$$\frac{V\mu\ell}{k^{1/2}\sigma \cos \theta}$$

V, velocity, ℓ/t
μ, absolute viscosity, $m/\ell t$
ℓ, characteristic length, ℓ
k, permeability, ℓ^2
σ, surface tension, m/t^2
θ, contact angle, 1
Flow in porous media
Ref. 2

NO NAME 4

$$\frac{\text{Viscous pressure}}{\text{Gravity pressure}}$$

$$\frac{V\mu}{(k_L k_H)^{1/2} g \Delta\rho}$$

V, velocity, ℓ/t
μ, absolute viscosity, $m/\ell t$
k_L, longitudinal permeability, ℓ^2
k_H, horizontal permeability, ℓ^2
g, gravitational acceleration, ℓ/t^2
$\Delta\rho$, mass density difference between fluids, m/ℓ^3
Two phase flow in porous media
Ref. 2

NO NAME 5

$$\frac{\text{Viscous force}}{\text{Surface tension force}}$$

$$\frac{\mu D V}{\sigma \ell}$$

μ, absolute viscosity, $m/\ell t$
D, bubble or drop diameter, ℓ
V, velocity, ℓ/t
σ, interfacial tension, m/t^2
ℓ, characteristic length, ℓ
Two phase flow
Disperse media
Ref. 21

NUSSELT (heat transfer)

$$\frac{\text{Total heat transfer}}{\text{Conductive heat transfer}}$$

$$\frac{h\ell}{k\Delta T}$$

h, heat transferred/area × time, m/t^3
ℓ, characteristic length, ℓ
k, heat conductivity of gas, $m\ell/t^3T$
ΔT, temperature difference (wall-gas stream), T
Convective heat transfer
Ref. 14

NUSSELT (mass transfer)

$$\frac{\text{Mass diffusivity}}{\text{Molecular diffusivity}}$$

$$\frac{k_c\ell}{D_m}$$

k_c, mass transfer coefficient, ℓ/t
ℓ, characteristic length, ℓ
D_m, molecular diffusivity, ℓ^2/t
$k_c = \tau/\rho V$
τ, fluid shear stress at surface, $m/\ell t^2$
ρ, mass density of fluid, m/ℓ^3
V, fluid velocity, ℓ/t
Mass transfer
Same as Sherwood
Ref. 13

NUSSELT FILM THICKNESS

$$\left(\frac{\rho^2 g}{\mu^2}\right)^{1/3} \ell_F$$

ρ, mass density, m/ℓ^3
g, gravitational acceleration, ℓ/t^2
μ, absolute viscosity, $m/\ell t$
ℓ_F, film thickness, ℓ
Falling films
Ref. 30

OCVIRK

$$\frac{\text{Bearing load force}}{\text{Viscous force}}$$

$$\frac{F}{\mu V}\left(\frac{c}{r}\,\frac{D}{b}\right)^2$$

F, bearing load/length, m/t^2
μ, absolute viscosity, $m/\ell t$
V, surface speed, ℓ/t
c, clearance width, ℓ
r, shaft radius, ℓ
D, shaft diameter, ℓ
b, bearing length, ℓ
Bearing lubrication
See Hersey, Sommerfeld
Ref. 30

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OHNESORGE

$$\frac{\text{Viscous force}}{\text{Surface tension force}}$$

$$\frac{\mu}{(\ell\rho\sigma)^{1/2}}$$

μ, absolute viscosity, $m/\ell t$
ℓ, characteristic length, ℓ
ρ, mass density, m/ℓ^3
σ, surface tension, m/t^2
Capillary jets
Low-g slosh
Ref. 18, 30

PARTICLE

$$\frac{UV}{g\ell}$$

U, terminal, free fall velocity of particle, ℓ/t
V, fluid velocity, ℓ/t
g, gravitational acceleration, ℓ/t^2
ℓ, characteristic length, ℓ
Dust deposit in ducts
Similar to Froude
Ref. 6

PECLET (heat transfer)

$$\frac{\text{Heat convection}}{\text{Heat conduction}}$$

$$\frac{\rho c_p V \ell}{k}$$

ρ, mass density, m/ℓ^3
c_p, specific heat at constant pressure, ℓ^2/t^2T
V, velocity, ℓ/t
ℓ, characteristic length, ℓ
k, heat conductivity, $m\ell/t^3T$
Forced convection
See Graetz
Equals Reynolds/Prandtl
Ref. 3

PECLET (mass transfer)

$$\frac{\text{Bulk mass transfer}}{\text{Diffusive mass transfer}}$$

$$\frac{\ell V}{D}$$

ℓ, characteristic length, ℓ
V, velocity, ℓ/t
D, mass diffusivity, ℓ^2/t
Equals Reynolds/Schmidt
Mass transfer
Ref. 30

PIPELINE

$$\frac{\text{Maximum water hammer pressure rise}}{2 \times \text{Static pressure}}$$

$$\frac{aV}{2gH}$$

a, pressure wave velocity, ℓ/t
V, fluid velocity, ℓ/t
g, gravitational acceleration, ℓ/t^2
H, static head, ℓ
Water hammer
Ref. 30

PLASTICITY

$$\frac{\text{Yield stress}}{\text{Viscous stress}}$$

$$\frac{\sigma\ell}{\mu V}$$

σ, stress at elastic yield, $m/\ell t^2$
ℓ, characteristic length, ℓ
μ, absolute viscosity in plastic state, $m/\ell t$
V, velocity, ℓ/t
Flow of plastics
Equals Bingham
Ref. 30

POISEUILLE

$$\frac{\text{Pressure force}}{\text{Viscous force}}$$

$$\frac{D^2}{\mu V}\frac{dp}{d\ell}$$

D, pipe diameter, ℓ
μ, absolute viscosity, $m/\ell t$
V, velocity, ℓ/t
$dp/d\ell$, pressure gradient, $m/\ell^2 t^2$
Laminar fluid friction
Ref. 30

POISSON

$$\frac{\text{Lateral contraction}}{\text{Longitudinal extension}}$$

$$\frac{E}{2G}-1$$

E, tension modulus of elasticity, $m/\ell t^2$
G, torsion modulus of elasticity, $m/\ell t^2$
Elasticity
Deformation of solid bodies
Ref. 9

POMERANTSEV

$$\frac{H\ell^2}{k\Delta T}$$

H, heat liberated/volume time, $m/\ell t^3$
ℓ, characteristic length, ℓ
k, heat conductivity, $m\ell/t^3T$
ΔT, temperature difference, T
Heat transfer with heat source in medium
Ref. 30

POSNOV

$$\frac{\sigma\Delta T}{\Delta M}$$

σ, thermal gradient, $1/T$
ΔT, temperature difference, T
ΔM, difference of body moisture content, m/m, 1
Capillary-porous, moist bodies
Ref. 10

POWER

$$\frac{\text{Paddle drag}}{\text{Inertia force}}$$

$$\frac{P}{\ell^5 \rho n^3}$$

P, agitator power, $m\ell^2/t^3$
ℓ, characteristic length, ℓ
ρ, mass density, m/ℓ^3
n, rotation speed, $1/t$
Agitators, fans
Ref. 30

PRANDTL (heat transfer)

$$\frac{\text{Momentum diffusivity}}{\text{Thermal diffusivity}}$$

$$\frac{c_p \mu}{k}$$

c_p, specific heat at constant pressure, $\ell^2/t^2 T$
μ, absolute viscosity, $m/\ell t$
k, heat conductivity, $m\ell/t^3 T$
Convection
A fluid property
Ref. 13, 14

PRANDTL (mass transfer)

$$\frac{\text{Momentum diffusivity}}{\text{Mass diffusivity}}$$

$$\frac{\mu}{\rho D}$$

μ, absolute viscosity, $m/\ell t$
ρ, mass density, m/ℓ^3
D, mass diffusivity, ℓ^2/t
Diffusion in flowing systems
A material property
Equals Schmidt
Ref. 30

PRANDTL VELOCITY RATIO

$$\left(\frac{\text{Inertia force}}{\text{Wall shear force}}\right)^{1/2}$$

$$V\left(\frac{\rho}{\tau}\right)^{1/2}$$

V, velocity, ℓ/t
ρ, mass density, m/ℓ^3
τ, wall shear stress, $m/\ell t^2$
Turbulent flow
See Fanning
Ref. 29, definition only

PREDVODITLEV

$$\frac{\text{Rate of change of temperature of medium}}{\text{Rate of change of temperature of body}}$$

$$\frac{\Gamma \ell^2}{\alpha T_o}$$

Γ, rate of change of temperature of medium, T/t
ℓ, characteristic length, ℓ
α, thermal diffusivity, ℓ^2/t
T_o initial temperature of body, T
Heat transfer of immersed body
Ref. 30

RADIATION PRESSURE

$$\frac{\text{Radiation pressure}}{\text{Gas pressure}}$$

$$\frac{a_R T^4}{3p}$$

a_R, Stefan-Boltzmann constant, $m/\ell t^2 T^4$ (7.67×10^{-15} erg/cm^3 °K^4)
T, temperature, T
p, pressure, $m/\ell t^2$
High temperature gas flow
Ref. 23

RAYLEIGH

$$\frac{\text{Gravity}}{\text{Thermal diffusivity}}$$

$$\frac{c_p \rho^2 g \ell^3 \beta \Delta T}{\mu k}$$

c_p, specific heat at constant pressure, ℓ^2/t^2T
ρ, mass density, m/ℓ^3
g, gravitational acceleration, ℓ/t^2
ℓ, characteristic length, ℓ
β, volume expansion coefficient with temperature, $1/T$
ΔT, temperature difference, T
μ, absolute viscosity, $m/\ell t$
k, heat conductivity, $m\ell/t^3T$

Free convection
Equals Prandtl × Grashof
Ref. 2, 16

REECH

$$\frac{\text{Gravity force}}{\text{Inertia force}}$$

$$\frac{g\ell}{V^2}$$

g, gravitational acceleration, ℓ/t^2
ℓ, characteristic length, ℓ
V, velocity, ℓ/t
Surface boats
Gravity affected motions
Equals 1/Froude
Ref. 30

REGIER

$$\frac{b\omega\mu^{1/2}}{a}$$

b, wing half chord, ℓ
ω, angular frequency, $1/t$
a, sonic speed, ℓ/t
μ, mass ratio, 1

$$\mu=\frac{m}{\pi\rho b^2}$$

m, wing mass/length, m/ℓ
ρ, mass density of fluid, m/ℓ^3
Transonic wing flutter
A modified Strouhal
Ref. 27

REYNOLDS

$$\frac{\text{Inertia force}}{\text{Viscous force}}$$

$$\frac{\rho V \ell}{\mu}$$

ρ, mass density, m/ℓ^3
V, velocity, ℓ/t
ℓ, characteristic length, ℓ
μ, absolute viscosity, $m/\ell t$
Flow of real fluids
Also called Damköhler's Fifth
Ref. 1

RICHARDSON

$$\frac{\text{Buoyant force}}{\text{Turbulent force}}$$

$$\frac{g \ell \Delta\rho}{2q}$$

g, gravitational acceleration, ℓ/t^2
ℓ, characteristic length, ℓ
$\Delta\rho$, density difference, m/ℓ^3
q, dynamic pressure, $\rho V^2/2$, $m/\ell t^2$
V, velocity, ℓ/t
Atmospheric shear
Ref. 12

ROSSBY

$$\frac{\text{Inertia force}}{\text{Coriolis force}}$$

$$\frac{V}{2\omega\ell}$$

V, velocity, ℓ/t
ω, angular velocity, $1/t$
ℓ, characteristic length, ℓ
Air and ocean currents
Fluid spinup
Ref. 2, 15

RUSSELL

$$\frac{\text{Inertia force}}{\text{Buoyancy force}}$$

$$\frac{U}{Nh}$$

U, wind speed, ℓ/t
h, height of obstacle, ℓ
N, natural vertical frequency of an element of fluid about its equilibrium altitude in a density stratified atmosphere, $1/t$:

$$N = \left(-\frac{g}{\rho}\frac{d\rho}{dt}\right)^{1/2}$$

g, gravitational acceleration, ℓ/t^2
ρ, mass density, m/ℓ^3
z, vertical coordinate, ℓ

Waves in stratified flow
Ref. 33

SACHS

$$\frac{rp_0^{1/3}}{E^{1/3}}$$

r, distance from explosive to reference point, ℓ
p_0, atmospheric pressure, $m/\ell t^2$
E, explosive energy, $m\ell^2/t^2$
Surface explosions
Ref. 31

SARRAU

$$\frac{\text{Inertia force}}{\text{Elastic force}}$$

$$\frac{V}{a}$$

V, velocity, ℓ/t
a, sonic velocity, ℓ/t
Compressible flow
Equals Mach
Ref. 30

SCHILLER

$$\left(\frac{\text{Reynolds}}{2 \times \text{Newton}}\right)^{1/3}$$

Flow over immersed bodies
Ref. 13

SCHMIDT

$$\frac{\text{Momentum diffusivity}}{\text{Mass diffusivity}}$$

$$\frac{\mu}{\rho D}$$

μ, absolute viscosity, $m/\ell t$
ρ, mass density m/ℓ^3
D, mass diffusivity, ℓ^2/t
Diffusion in flowing systems
A fluid property
Equals Prandt/Lewis, Colburn
Ref. 13, 16

SEMENOV

$$\frac{\text{Mass diffusivity}}{\text{Thermal diffusivity}}$$

$$\frac{D\rho c_p}{k}$$

D, mass diffusivity, ℓ^2/t
ρ, mass density, m/ℓ^3
c_p, specific heat at constant pressure, ℓ^2/t^2T
k, heat conductivity, $m\ell/t^3T$
Heat and mass transfer
A fluid property
Equals Lewis, Prandtl/Schmidt
Ref. 30

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SHERWOOD

$$\frac{\text{Mass diffusivity}}{\text{Molecular diffusivity}}$$

$$\frac{k_c \ell}{D_m}$$

k_c, mass transfer coefficient, ℓ/t
ℓ, characteristic length, ℓ
D_m, molecular diffusivity, ℓ^2/t
$k_c = \tau/\rho V$
τ, fluid shear stress at surface, $m/\ell t^2$
ρ, mass density of fluid, m/ℓ^3
V, fluid velocity, ℓ/t
Mass transfer
Same as Nusselt (mass transfer)
Ref. 13

SLOSH TIME

$$\left(\frac{\sigma}{\rho R^3}\right)^{1/2} t$$

σ, surface tension, m/t^2
ρ, mass density, m/ℓ^3
R, tank radius, ℓ
t, time, t
Fluid slosh in low gravity field
Ref. 28

SMOLUCKOWSKI

$$\frac{\text{Characteristic body length}}{\text{Molecular mean free path}}$$

$$\frac{\ell}{L}$$

ℓ, characteristic length, ℓ
L, length of mean free path of molecules, ℓ
Rarefied gas flows
Equals 1/Knudsen
Ref. 29

SOMMERFELD

$$\frac{\text{Viscous force}}{\text{Load force}}$$

$$\frac{P\psi^2}{\mu\omega}$$

P, bearing load/area, $m/\ell t^2$
ψ, radial clearance/diameter, 1
μ, absolute viscosity, $m/\ell t$
ω, angular velocity, $1/t$
Lubrication
See Hersey, Ocvirk
Ref. 29, definition only

SPECIFIC HEAT RATIO

$$\frac{\text{Specific heat at constant pressure}}{\text{Specific heat at constant volume}}$$

$$\frac{c_p}{c_v}$$

c_p, specific heat at constant pressure, ℓ^2/t^2T
c_v, specific heat at constant volume, ℓ^2/t^2T
Gas flow
A material property
Ref. 2

SPECIFIC SPEED

$$\frac{\omega (Q_v)^{1/2}}{(gh)^{3/4}}$$

ω, rotational speed, $1/t$
Q_v, volume rate of flow, ℓ^3/t
g, gravitational acceleration, ℓ/t^2
h, head produced per stage, ℓ
Pumps
Ref. 30

SQUEEZE

$$\frac{12\mu\omega}{p_a}\left(\frac{R}{c}\right)^2$$

μ, absolute viscosity, $m/\ell t$
ω, angular frequency, $1/t$
p_a, ambient pressure, $m/\ell t^2$
R, radius, ℓ
c, unloaded film thickness, ℓ
Double squeeze film damping
Ref. 20

STANTON

$$\frac{\text{Heat transferred to fluid}}{\text{Heat transported by fluid}}$$

$$\frac{h}{\rho c_p V}$$

h, heat transfer coefficient, m/t^3T
ρ, mass density, m/ℓ^3
c_p, specific heat at constant pressure, ℓ^2/t^2T
V, velocity, ℓ/t
Forced convection
Ref. 3

STEFAN

$$\frac{\text{Heat radiated}}{\text{Heat conducted}}$$

$$\frac{\sigma A_1 T^4}{kA_2 \dfrac{\Delta T}{\Delta \ell}}$$

σ, Stefan-Boltzmann constant, m/t^3T^4
A_1, radiating area, ℓ^2
T, temperature, T
k, heat conductivity, $m\ell/t^3T$
A_2, conducting area, ℓ^2
$\Delta T/\Delta \ell$, temperature gradient, T/ℓ
Heat balance
Ref. 16

STOKES

$$\frac{\text{Viscous force}}{\text{Gravity force}}$$

$$\frac{\mu V}{\rho g \ell^2}$$

μ, absolute viscosity, $m/\ell t$
V, velocity, ℓ/t
ρ, mass density, m/ℓ^3
g, gravitational acceleration, ℓ/t^2
ℓ, characteristic length, ℓ
Slow flow
Equals 1/Jeffrey
See Galileo, Archimedes
Ref. 16

STROUHAL

$$\frac{\text{Vibration speed}}{\text{Translation speed}}$$

$$\frac{\ell \omega}{V}$$

ℓ, characteristic length, ℓ
ω, angular frequency of vibration, $1/t$
V, translation speed, ℓ/t
Shed vortices
Wind induced vibrations
Ref. 1

SURATMAN

$$\frac{\rho \ell \sigma}{\mu^2}$$

ρ, mass density, m/ℓ^3
ℓ, characteristic length, ℓ
σ, surface tension, m/t^2
μ, absolute viscosity, $m/\ell t$
Particle dynamics
Ref. 30

SURFACE VISCOSITY

$$\frac{\mu_s}{\mu d}$$

μ_s, surface viscosity, m/t
μ, absolute viscosity of liquid, $m/\ell t$
d, depth of liquid layer, ℓ
Convection cells in liquid layers with surfactants
Ref. 35

TAYLOR

$$\frac{\text{Centrifugal force}}{\text{Viscous force}}$$

$$\frac{\omega^2 d^4}{\nu^2}$$

ω, angular velocity, $1/t$
d, clearance between cylinders, ℓ
ν, kinematic viscosity, ℓ/t
Stability of flow between rotating cylinders
Ref. 2

THOMA

$$\frac{\text{Pressure margin above cavitation}}{\text{Pressure rise in pump}}$$

$$\frac{p_1 - p_v}{p_2 - p_1}$$

p_1, total pressure at pump inlet, $m/\ell t^2$
p_2, total pressure at pump outlet, $m/\ell t^2$
p_v, vapor pressure, $m/\ell t^2$
Liquid pump cavitation
See Cavitation
Ref. 16

THOMSON

$$\frac{tV}{\ell}$$

t, characteristic time, t
ℓ, characteristic length, ℓ
V, velocity, ℓ/t
Ref. 30

THRING

$$\frac{\text{Bulk heat transport}}{\text{Radiative heat transport}}$$

$$\frac{\rho c_p V}{e\eta T^3}$$

ρ, mass density, m/ℓ^3
c_p, specific heat at constant pressure, ℓ^2/t^2T
V, velocity, ℓ/t
e, surface emissivity, 1
η, Stefan-Boltzmann constant, m/T^4t^3
T, temperature, T
Radiation
Equals Boltzmann
Ref. 30

TOMS

$$\frac{\text{Fuel weight}}{\text{Air drag}}$$

$$\frac{Q}{\rho V^3 \ell}$$

Q, fuel rate (weight/time), $m\ell/t^3$
ρ, mass density, m/ℓ^3
V, velocity, ℓ/t
ℓ, characteristic length, ℓ
Airplane merit
Ref. 5

TRUNCATION

$$\frac{\text{Shear stress}}{\text{Normal stress}}$$

$$\frac{\mu\alpha}{p}$$

μ, absolute viscosity, $m/\ell t$
α, shear strain rate, $1/t$
p, pressure, $m/\ell t^2$
Viscous flow
Ref. 30

VISCOELASTIC

$$\frac{\text{Elastic force}}{\text{Viscous force}}$$

$$\frac{G}{\omega\mu}$$

G, shear modulus of elasticity, $m/\ell t^2$
ω, frequency, $1/t$
μ, absolute viscosity, $m/\ell t$
Dynamic viscoelasticity
Ref. 9

WEBER

$$\frac{\text{Inertia force}}{\text{Surface tension force}}$$

$$\frac{\rho V^2 \ell}{\sigma}$$

ρ, mass density, m/ℓ^3
V, velocity, ℓ/t
ℓ, characteristic length, ℓ
σ, surface tension, m/t^2
Capillary flow
Slosh
Ripples
Ref. 2

WEISSENBERG

$$\frac{(\lambda_1 - \lambda_2)V}{D}$$

V, velocity, ℓ/t
D, jet diameter, ℓ
λ_1, λ_2, time constants, t, from:
$\tau + \lambda_1\dot{\tau} = -\mu_0(\Delta + \lambda_2\dot{\Delta})$
τ, shear stress, $m/\ell t^2$
μ_0, zero shear viscosity, $m/\ell t$
Δ, rate of deformation, $1/t$
$\cdot$, d/dt
Viscoelastic jets
Ref. 18

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