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Characteristic numbers

Grandeurs et unités —

Partie 11: Nombres caractéristiques

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 12, *Quantities and units*, in collaboration with Technical Committee IEC/TC 25, *Quantities and units*.

This second edition cancels and replaces the first edition (ISO 80000-11:2008), which has been technically revised.

The main changes compared to the previous edition are as follows:

— the table giving the quantities and units has been simplified;

— all items have been revised in terms of the layout of the definitions, and a worded definition has been added to each item;

— the number of items has been increased from 25 to 108 (concerns all Clauses);

— item 11-9.2 (Landau-Ginzburg number) has been transferred in this document from ISO 80000-12:2009 (revised as ISO 80000-12:2019).

A list of all parts in the ISO 80000 and IEC 80000 series can be found on the ISO and IEC websites.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Characteristic numbers are physical quantities of unit one, although commonly and erroneously called “dimensionless” quantities. They are used in the studies of natural and technical processes, and (can) present information about the behaviour of the process, or reveal similarities between different processes.

Characteristic numbers often are described as ratios of forces in equilibrium; in some cases, however, they are ratios of energy or work, although noted as forces in the literature; sometimes they are the ratio of characteristic times.

Characteristic numbers can be defined by the same equation but carry different names if they are concerned with different kinds of processes.

Characteristic numbers can be expressed as products or fractions of other characteristic numbers if these are valid for the same kind of process. So, the clauses in this document are arranged according to some groups of processes.

As the amount of characteristic numbers is tremendous, and their use in technology and science is not uniform, only a small amount of them is given in this document, where their inclusion depends on their common use. Besides, a restriction is made on the kind of processes, which are given by the Clause headings. Nevertheless, several characteristic numbers are found in different representations of the same physical information, e.g. multiplied by a numerical factor, as the square, the square root, or the inverse of another representation. Only one of these have been included, the other ones are declared as deprecated or are mentioned in the remarks column.

Quantities and units —

Part 11: Characteristic numbers

1 Scope

This document gives names, symbols and definitions for characteristic numbers used in the description of transport and transfer phenomena.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

Names, symbols and definitions for characteristic numbers are given in Clauses 4 to 9.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

4 Momentum transfer

Table 1 gives the names, symbols and definitions of characteristic numbers used to characterize processes in which momentum transfer plays a predominant role. The transfer of momentum (ISO 80000-4) basically occurs during a collision of 2 bodies, and is governed by the law of momentum conservation. Energy dissipation can occur. In a more generalized meaning momentum transfer occurs during the interaction of 2 subsystems moving with velocity v relative to each other. Typically, one of the subsystems is solid and possibly rigid, with a characteristic length, which can be a length, width, radius, etc. of a solid object, often the effective length is given by the ratio of a body's volume to the area of its surface.

The other subsystem is a fluid, in general liquid or gaseous, with the following properties amongst others:

— mass density ρ (ISO 80000-4);

— dynamic viscosity η (ISO 80000-4);

— kinematic viscosity $\nu = \eta / \rho$ (ISO 80000-4), or

— pressure drop Δp (ISO 80000-4).

The field of science is mainly fluid dynamics (mechanics). Characteristic numbers of this kind allow the comparison of objects of different sizes. They also can give some estimation about the change of laminar flow to turbulent flow.

Table 1 — Characteristic numbers for momentum transfer

No.	Name	Symbol	Definition	Remarks
11-4.1	Reynolds number	*Re*	quotient of inertial forces and viscous forces in a fluid flow, expressed by $Re = \frac{\rho v l}{\eta} = \frac{v l}{\nu}$; where ρ is mass density (ISO 80000-4), v is speed (ISO 80000-3), l is characteristic length (ISO 80000-3), η is dynamic viscosity (ISO 80000-4), and ν is kinematic viscosity (ISO 80000-4)	The value of the Reynolds number gives an estimate on the flow state: laminar flow or turbulent flow. In rotating movement, the speed $v = \omega l$, where l is the distance from the rotation axis and ω *is* the angular velocity.
11-4.2	Euler number	*Eu*	relationship between pressure drop in a flow and the kinetic energy per volume for flow of fluids in a pipe, expressed by $Eu = \frac{\Delta p}{\rho v^2}$; where Δp is drop of pressure (ISO 80000-4), ρ is mass density (ISO 80000-4), and v is speed (ISO 80000-3)	The Euler number is used to characterize losses in the flow. A modification of the Euler number is considering the dimensions of the containment (pipe): $Eu' = \frac{d}{l} Eu$; where d is inner diameter (ISO 80000-3) of the pipe, and l is length (ISO 80000-3).
11-4.3	Froude number	*Fr*	quotient of a body's inertial forces and its gravitational forces for flow of fluids, expressed by $Fr = \frac{v}{\sqrt{l g}}$; where v is speed (ISO 80000-3) of flow, l is characteristic length (ISO 80000-3), and g is acceleration of free fall (ISO 80000-3)	The Froude number can be modified by buoyancy. Sometimes the square and sometimes the inverse of the Froude number as defined here is wrongly used.

Table 1 *(continued)*

No.	Name	Symbol	Definition	Remarks
11-4.4	Grashof number	*Gr*	quotient of buoyancy forces due to thermal expansion which results in a change of mass density and viscous forces for free convection due to temperature differences, expressed by $Gr = l^3 g \alpha_V \Delta T / \nu^2$; where l is characteristic length (ISO 80000-3), g is acceleration of free fall (ISO 80000-3), α_V is thermal cubic expansion coefficient (ISO 80000-5), ΔT is difference of thermodynamic temperature T (ISO 80000-5) between surface of the body and the fluid far away from the body, and ν is kinematic viscosity (ISO 80000-4)	Heating can occur near hot vertical walls, in pipes, or by a bluff body. The characteristic length can be the vertical height of a hot plate, the diameter of a pipe, or the effective length of a body. See also Rayleigh number (item 11-5.3).
11-4.5	Weber number	*We*	relation between inertial forces and capillary forces due to surface tension at the interface between two different fluids, expressed by $We = \rho v^2 l / \gamma$; where ρ is mass density (ISO 80000-4), v is speed (ISO 80000-3), l is characteristic length (ISO 80000-3), and γ is surface tension (ISO 80000-4)	The fluids can be gases or liquids. The different fluids often are drops moving in a gas or bubbles in a liquid. The characteristic length is commonly the diameter of bubbles or drops. The square root of the Weber number is called Rayleigh number. Sometimes the square root of the Weber number as defined here is called the Weber number. That definition is deprecated. Interfaces only exist between two fluids which are not miscible.
11-4.6	Mach number	*Ma*	quotient of the speed of flow and the speed of sound, expressed by $Ma = v / c$; where v is speed (ISO 80000-3) of the body, and c is speed of sound (ISO 80000-8) in the fluid	The Mach number represents the relationship of inertial forces compared to compression forces. For an ideal gas $c = \sqrt{\gamma \frac{p}{\rho}} = \sqrt{\gamma \frac{RT}{M}} = \sqrt{\gamma \frac{kT}{m}}$; where γ is ratio of the specific heat capacity (ISO 80000-5).

Table 1 *(continued)*

No.	Name	Symbol	Definition	Remarks
11-4.7	Knudsen number	*Kn*	quotient of free path length of a particle and a characteristic length, expressed by $Kn = \lambda / l$; where λ is mean free path (ISO 80000-9), and l is characteristic length (ISO 80000-3)	The Knudsen number is a measure to estimate whether the gas in flow behaves like a continuum. The characteristic length, *l*, can be a characteristic size of the gas flow region like a pipe diameter.
11-4.8	Strouhal number; Thomson number	*Sr*, *Sh*	relation between a characteristic frequency and a characteristic speed for unsteady flow with periodic behaviour, expressed by $Sr = f\,l / v$; where f is frequency (ISO 80000-3) of vortex shedding, l is characteristic length (ISO 80000-3), and v is speed (ISO 80000-3) of flow	The characteristic length, *l*, can be the diameter of an obstacle in the flow which can cause vortex shedding, or the length of it.
11-4.9	drag coefficient	c_D	relation between the effective drag force and inertial forces for a body moving in a fluid, expressed by $c_D = \frac{2F_D}{\rho v^2 A}$; where F_D is drag force (ISO 80000-4) on the body, ρ is mass density (ISO 80000-4) of the fluid, v is speed (ISO 80000-3) of the body, and A is cross-sectional area (ISO 80000-3)	The drag coefficient is strongly dependant on the shape of the body.
11-4.10	Bagnold number	*Bg*	quotient of drag force and gravitational force for a body moving in a fluid, expressed by $Bg = \frac{c_D \rho v^2}{l g \rho_b}$; where c_D is drag coefficient (item 11-4.9) of the body, ρ is mass density (ISO 80000-4) of the fluid, v is speed (ISO 80000-3) of the body, l is characteristic length (ISO 80000-3), g is acceleration of free fall (ISO 80000-3), and ρ_b is mass density (ISO 80000-4) of the body	The characteristic length, *l*, is the body's volume divided by its cross-sectional area.

Table 1 *(continued)*

No.	Name	Symbol	Definition	Remarks
11-4.11	Bagnold number <solid particles>	Ba_2	quotient of drag force and viscous force in a fluid transferring solid particles, expressed by $Ba_2 = \frac{\rho_s d^2 \dot{\gamma}}{\eta} \sqrt{1/\left(f_s^{1/2} - 1\right)}$; where ρ_s is mass density (ISO 80000-4) of particles, d is diameter (ISO 80000-3) of particles, $\dot{\gamma} = v/d$ is shear rate time-derivative of shear strain (ISO 80000-4), η is dynamic viscosity (ISO 80000-4) of fluid, and f_s is volumic fraction of solid particles	
11-4.12	lift coefficient	c_l, c_A	quotient of the lift force available from a wing at a given angle and the inertial force for a wing shaped body moving in a fluid, expressed by $c_l = \frac{2F_l}{\rho v^2 S} = \frac{F_l}{qS}$; where F_l is lift force (ISO 80000-4) on the wing, ρ is mass density (ISO 80000-4) of the fluid, v is speed (ISO 80000-3) of the body, $S = A \cos \alpha$ is effective area (ISO 80000-3) when α is the angle of attack and A is area of the wing, and $q = \rho v^2 / 2$ is dynamic pressure.	The lift coefficient is dependant on the shape of the wing.
11-4.13	thrust coefficient	c_t	quotient of the effective thrust force available from a propeller and the inertial force in a fluid, expressed by $c_t = F_T / \left(\rho n^2 d^4\right)$; where F_T is thrust force (ISO 80000-4) of the propeller, ρ is mass density (ISO 80000-4) of the fluid, n is rotational frequency (ISO 80000-3), and d is tip diameter (ISO 80000-3) of the propeller	The thrust coefficient is dependant on the shape of the propeller.

Table 1 *(continued)*

No.	Name	Symbol	Definition	Remarks
11-4.14	Dean number	*Dn*	relation between centrifugal force and inertial force, for flows of fluids in curved pipes, expressed by $Dn = \frac{2vr}{\nu}\sqrt{\frac{r}{R}}$; where v is (axial) speed (ISO 80000-3), r is radius (ISO 80000-3) of the pipe, ν is kinematic viscosity (ISO 80000-4) of the fluid, and R is radius of curvature (ISO 80000-3) of the path of the pipe	
11-4.15	Bejan number	*Be*	quotient of mechanical work and frictional energy loss in fluid dynamics in a pipe, expressed by $Be = \frac{\Delta p l^2}{\eta \nu} = \frac{\rho \Delta p\, l^2}{\eta^2}$; where Δp is drop of pressure (ISO 80000-4) along the pipe, l is characteristic length (ISO 80000-3), η is dynamic viscosity (ISO 80000-4), ν is kinematic viscosity (ISO 80000-4), and ρ is mass density (ISO 80000-4).	A similar number exists for heat transfer (item 11-5.9). The kinematic viscosity is also called momentum diffusivity.
11-4.16	Lagrange number	*Lg*	quotient of mechanical work and frictional energy loss in fluid dynamics in a pipe, expressed by $Lg = \frac{l \Delta p}{\eta v}$; where l is length (ISO 80000-3) of the pipe, Δp is drop of pressure (ISO 80000-4) along the pipe, η is dynamic viscosity (ISO 80000-4), and v is speed (ISO 80000-3)	The Lagrange number is also given by $La = Re \cdot Eu$; where Re is the Reynolds number (item 11-4.1), and Eu is the Euler number (item 11-4.2).

Table 1 *(continued)*

No.	Name	Symbol	Definition	Remarks
11-4.17	Bingham number; plasticity number	*Bm*, *Bn*	quotient of yield stress and viscous stress in a viscous material for flow of viscoplastic material in channels, expressed by $Bm = \frac{\tau d}{\eta v}$; where τ is shear stress (ISO 80000-4), d is characteristic diameter (ISO 80000-3), e.g. effective channel width, η is dynamic viscosity (ISO 80000-4), and v is speed (ISO 80000-3)	
11-4.18	Hedström number	*He*, *Hd*	quotient of yield stress and viscous stress of a viscous material at flow limit for visco-plastic material in a channel, expressed by $He = \frac{\tau_0 d^2 \rho}{\eta^2}$; where τ_0 is shear stress (ISO 80000-4) at flow limit, d is characteristic diameter (ISO 80000-3), e.g. effective channel width, ρ is mass density (ISO 80000-4), and η is dynamic viscosity (ISO 80000-4)	
11-4.19	Bodenstein number	*Bd*	mathematical expression of the transfer of matter by convection in reactors with respect to diffusion, $Bd = vl/D$; where v is speed (ISO 80000-3), l is length (ISO 80000-3) of the reactor, and D is diffusion coefficient (ISO 80000-9)	The Bodenstein number is also given by $Bd = Pe^* = Re \cdot Sc$; where Pe^* is the Péclet number for mass transfer (item 11-6.2), Re is the Reynolds number (item 11-4.1), and $Sc = \eta/(\rho D) = \nu/D$ is Schmidt number (item 11-7.2).

Table 1 *(continued)*

No.	Name	Symbol	Definition	Remarks
11-4.20	Rossby number; Kiebel number	*Ro*	quotient of inertial forces and Coriolis forces in the context of transfer of matter in geophysics, expressed by $Ro = v/(2l\omega_E \sin\varphi)$; where v is speed (ISO 80000-3) of motion, l is characteristic length (ISO 80000-3), the scale of the phenomenon, ω_E is angular velocity (ISO 80000-3) of the Earth's rotation, and φ is angle (ISO 80000-3) of latitude	The Rossby number represents the effect of Earth's rotation on flow in pipes, rivers, ocean currents, tornadoes, etc. The quantity $\omega_E \sin\varphi$ is called Coriolis frequency.
11-4.21	Ekman number	*Ek*	quotient of viscous forces and Coriolis forces in the context of transfer of matter for the flow of a rotating fluid, expressed by $Ek = \nu/(2l^2\omega_E \sin\varphi)$; where ν is kinematic viscosity (ISO 80000-4), l is characteristic length (ISO 80000-3), the scale of the phenomenon, ω_E is angular frequency (ISO 80000-3) of the Earth's rotation, and φ is angle of latitude	In plasma physics, the square root of this number is used. The Ekman number is also given by $Ek = Ro/Re$; where Ro is the Rossby number (item 11-4.20), and Re is the Reynolds number (item 11-4.1).
11-4.22	elasticity number	*El*	relation between relaxation time and diffusion time in viscoelastic flows, expressed by $El = t_r \nu / r^2$; where t_r is relaxation time (ISO 80000-12), ν is kinematic viscosity (ISO 80000-4), and r is radius (ISO 80000-3) of pipe	See also Deborah number (item 11-7.8).

Table 1 *(continued)*

No.	Name	Symbol	Definition	Remarks
11-4.23	Darcy friction factor; Moody friction factor	f_D	representation of pressure loss in a pipe due to friction within a laminar or turbulent flow of a fluid in a pipe, expressed by $f_D = \frac{2\Delta p}{\rho v^2}\frac{d}{l}$; where Δp is drop of pressure (ISO 80000-4) due to friction, ρ is mass density (ISO 80000-4) of the fluid, v is (average) speed (ISO 80000-3) of the fluid in the pipe, d is diameter (ISO 80000-3) of the pipe, and l is length (ISO 80000-3) of the pipe	
11-4.24	Fanning number	f_n, f	relation between shear stress and dynamic pressure in the flow of a fluid in a containment, expressed by $f_n = \frac{2\tau}{\rho v^2}$; where τ is shear stress (ISO 80000-4) at the wall, ρ is mass density (ISO 80000-4) of the fluid, and v is speed (ISO 80000-3) of the fluid in the pipe	The Fanning number describes the flow of fluids in a pipe with friction at the walls represented by its shear stress. Symbol *f* may be used where no conflicts are possible.
11-4.25	Goertler number; Goertler parameter	*Go*	characterization of the stability of laminar boundary layer flows in transfer of matter in a boundary layer on curved surfaces, expressed by $Go = \frac{v l_b}{\nu}\sqrt{\left(\frac{l_b}{r_c}\right)}$; where v is speed (ISO 80000-3), l_b is boundary layer thickness (ISO 80000-3), ν is kinematic viscosity (ISO 80000-4), and r_c is radius of curvature (ISO 80000-3)	The Goertler number represents the ratio of centrifugal effects to viscous effects.

Table 1 *(continued)*

No.	Name	Symbol	Definition	Remarks
11-4.26	Hagen number	*Hg*, *Ha*	generalization of the Grashof number for forced or free convection in laminar flow, expressed by $Hg = -\frac{1}{\rho}\frac{\mathrm{d}p}{\mathrm{d}x}\frac{l^3}{\nu^2}$; where ρ is mass density (ISO 80000-4) of fluid, $\frac{\mathrm{d}p}{\mathrm{d}x}$ is gradient of pressure (ISO 80000-4), l is characteristic length (ISO 80000-3), and ν is kinematic viscosity (ISO 80000-4)	For free thermal convection with $\frac{\mathrm{d}p}{\mathrm{d}x} = \rho g \alpha_V \Delta T$, the Hagen number then coincides with the Grashof number (item 11-4.4). See also the Poiseuille number (item 11-4.28).
11-4.27	Laval number	*La*	quotient of speed and the (critical) sound speed at the throat of a nozzle, expressed by $La = v/\sqrt{(R_s T 2\gamma)/(\gamma+1)}$; where v is speed (ISO 80000-3), $R_s = \frac{R}{M}$ is specific gas constant, where R is molar gas constant (ISO 80000-9), and M is molar mass (ISO 80000-9), T is thermodynamic temperature (ISO 80000-5), and γ is ratio of the specific heat capacities (ISO 80000-5)	The Laval number is a specific kind of Mach number (item 11-4.6).
11-4.28	Poiseuille number	*Poi*	quotient of propulsive force by pressure and viscous force for a flow of fluids in a pipe, expressed by $Poi = -\frac{\Delta p}{l}\frac{d^2}{\eta v}$; where Δp is drop of pressure (ISO 80000-4) along the pipe, l is length (ISO 80000-3) of the pipe, d is diameter (ISO 80000-3) of the pipe, η is dynamic viscosity (ISO 80000-4) of the fluid, and v is characteristic speed (ISO 80000-3) of the fluid	The Poiseuille number is $Poi = 32$ for laminar flow in a round pipe. See also the Hagen number (item 11-4.26).

Table 1 *(continued)*

No.	Name	Symbol	Definition	Remarks
11-4.29	power number	*Pn*	quotient of power consumption by agitators due to drag and rotational inertial power in fluids, expressed by $Pn = P/(\rho n^3 d^5)$; where P is active power (IEC 80000-6) consumed by a stirrer, ρ is mass density (ISO 80000-4) of fluid, n is rotational frequency (ISO 80000-3), and d is diameter (ISO 80000-3) of stirrer	
11-4.30	Richardson number	*Ri*	quotient of potential energy and kinetic energy for a falling body, expressed by $Ri = gh/v^2$; where g is acceleration of free fall (ISO 80000-3), h is characteristic height (ISO 80000-3), and v is characteristic speed (ISO 80000-3)	In geophysics differences of these quantities are of interest.
11-4.31	Reech number	*Ree*	relation between the speed of an object submerged in water relative to the water, and wave propagation speed, expressed by $Ree = \sqrt{gl}/v$; where g is acceleration of free fall (ISO 80000-3), l is characteristic length (ISO 80000-3), and v is speed (ISO 80000-3) of the object relative to the water	The Reech number can be used to determine the resistance of a partially submerged object (e.g. a ship) of length *l* (in direction of the motion) moving through water. A similar quantity is defined as the Boussinesq number $Bs = v/\sqrt{2gl}$.
11-4.32	Stokes number <time-related>	*Stk*	quotient of friction and inertia forces for particles in a fluid or in a plasma, expressed by $Stk = t_r/t_a$; where t_r is relaxation time (ISO 80000-12) of particles to achieve fluid's velocity due to friction (viscosity), and t_a is time (ISO 80000-3) of fluid to alter its velocity under external influence	In most cases $t_r = l/v$; where *l* is characteristic length, and v is speed of fluid. The characteristic length can be the diameter of an obstacle or hole.

Table 1 *(continued)*

No.	Name	Symbol	Definition	Remarks
11-4.33	Stokes number <vibrating particles>	Stk_1	quotient of friction and inertia forces for the special case of particles vibrating in a fluid or plasma, expressed by $Stk_1 = \nu / (d^2 f)$; where ν is kinematic viscosity (ISO 80000-4) of the fluid or plasma, d is diameter (ISO 80000-3) of particle, and f is frequency (ISO 80000-3) of particle vibrations	Sometimes the inverse of this number is wrongly used.
11-4.34	Stokes number <rotameter>; power coefficient <rotameter>	Stk_2	Stokes number for calibration of rotameters metering vertical flows of fluids by means of a floating body, expressed by $Stk_2 = \frac{r^3 g m \rho}{\eta^2} \frac{(\rho_b - \rho)}{\rho_b} = \frac{r^3 g m}{\nu^2} \left(\frac{1}{\rho} - \frac{1}{\rho_b} \right)$; where r is ratio of pipe and float radii, g is acceleration of free fall (ISO 80000-3), m is mass (ISO 80000-4) of the body, ρ is mass density (ISO 80000-4) of the fluid, η is dynamic viscosity (ISO 80000-4) of the fluid, ρ_b is mass density (ISO 80000-4) of the body, and ν is kinematic viscosity (ISO 80000-4) of the fluid	In general use, this value is multiplied by 1,042. See also the Archimedes number (item 11-6.12).
11-4.35	Stokes number <gravity>	Stk_3	relation between viscous forces and gravity forces for particles falling in a fluid, expressed by $Stk_3 = v \nu / (g l^2)$; where v is characteristic speed (ISO 80000-3) of particles, ν is kinematic viscosity (ISO 80000-4) of the fluid, g is acceleration of free fall (ISO 80000-3), and l is length (ISO 80000-3) of fall	

Table 1 *(continued)*

No.	Name	Symbol	Definition	Remarks
11-4.36	Stokes number <drag>	Stk_4	quotient of drag force and internal friction forces for particles dragged in a fluid $Stk_4 = F_D/(\eta v l)$; where F_D is drag force (ISO 80000-4), η is dynamic viscosity (ISO 80000-4), v is speed (ISO 80000-3), and l is characteristic length (ISO 80000-3)	
11-4.37	Laplace number; Suratman number	La, Su	relation between capillary forces and viscous forces when characterizing free surface flow, expressed by $La = Su = \gamma \rho l/\eta^2$; where γ is surface tension (ISO 80000-4), ρ is mass density (ISO 80000-4) of the fluid, l is characteristic length (ISO 80000-3), and η is dynamic viscosity (ISO 80000-4) of the fluid	The Laplace number is also the ratio of surface tension to momentum transfer, especially dissipation, inside a fluid. The Laplace number is also given by $La = Su = 1/Oh^2 = Re^2/We$; where Oh is the Ohnesorge number (item 11-7.4), Re is the Reynolds number (item 11-4.1), and We is the Weber number (item 11-4.5).
11-4.38	Blake number	Bl	relation between inertial forces and viscous forces in a porous material, expressed by $Bl = \frac{v \rho l}{\eta (1-\varepsilon)}$; where v is speed (ISO 80000-3) of the fluid, ρ is mass density (ISO 80000-4) of the fluid, l is characteristic length (ISO 80000-3) defined as the volume of a particle divided by its surface area, η is dynamic viscosity (ISO 80000-4) of the fluid, and ε is porosity of the material (=void fraction)	The Blake number can be interpreted as a Reynolds number for flow in porous material.

Table 1 *(continued)*

No.	Name	Symbol	Definition	Remarks
11-4.39	Sommerfeld number	*So*, *Sm*	relation between viscous force and load force in a lubrication boundary, expressed by $So = \frac{\eta n}{p}\left(\frac{r}{c}\right)^2$; where η is dynamic viscosity (ISO 80000-4) of the lubricant, n is rotational frequency (ISO 80000-3), p is mean bearing pressure (ISO 80000-4), r is radius (ISO 80000-3) of the shaft, and c is radial distance (ISO 80000-3) between rotating shaft and annulus	Sometimes the inverse of this number is wrongly used.
11-4.40	Taylor number <momentum transfer>	*Ta*	relation between centrifugal force and viscous force of a rotating shaft, expressed by $Ta = 4\omega^2 l^4 / \nu^2$; where ω is angular velocity (ISO 80000-3) of rotation, l is length (ISO 80000-3) perpendicular to the rotation axis, and ν is kinematic viscosity (ISO 80000-4)	Sometimes the square root of this quantity is wrongly used. The Taylor number for a rotating shaft relative to an annulus is given by $Ta_a = (\omega/\nu)^2 r a^3$; where ω is angular velocity (ISO 80000-3) of the shaft, ν is kinematic viscosity (ISO 80000-4), $r = (r_2 + r_1)/2$ is mean radius (ISO 80000-3) of the annulus, and $a = (r_2 - r_1)$ is width of the annulus, where r_1 is inner radius of the annulus, and r_2 is outer radius of the annulus. Sometimes the square root of this quantity is used; this use is deprecated.

Table 1 *(continued)*

No.	Name	Symbol	Definition	Remarks
11-4.41	Galilei number	*Ga*	relation between gravitational force and viscous force in fluid films flowing over walls, expressed by $Ga = gl^3/\nu^2$; where g is acceleration of free fall (ISO 80000-3), l is characteristic length (ISO 80000-3), and ν is kinematic viscosity (ISO 80000-4) of the fluid	The Galilei number is also given by $Ga = Re^2 \cdot Ri$ or $Ga = Re^2 / Fr^2$; where Re is the Reynolds number (item 11-4.1), Ri is the Richardson number (item 11-4.30), and Fr is the Froude number (item 11-4.3).
11-4.42	Womersley number	*Wo*, α	relation between inertial forces and viscous forces in oscillating flows of fluids in pipes, expressed by $Wo = R\sqrt{\omega/\nu}$; where R is (effective) radius (ISO 80000-3) of the pipe, ω is angular frequency (ISO 80000-3) of oscillations, and ν is kinematic viscosity (ISO 80000-4)	The Womersley number is used for pulsating flows e.g. in blood flow.

5 Transfer of heat

Table 2 gives the names, symbols and definitions of characteristic numbers used to characterize processes in which heat transfer plays a predominant role. Transfer of heat (thermal energy) (ISO 80000-5), occurs either by (convective) transfer of matter with velocity v, or by conduction (diffusion) when a temperature difference exists, or by radiation. Transfer of heat needs a certain time t for a distance d which depends on the velocity v of convection or, in the case of conduction, on material constants like the thermal conductivity λ (ISO 80000-5) or the thermal diffusivity $\alpha = \lambda / \left(\rho c_p \right)$ (ISO 80000-5), which can depend on other quantities like temperature and pressure. Transfer of energy by radiation is considered to occur instantaneously.

Table 2 — Characteristic numbers for heat transfer

No.	Name	Symbol	Definition	Remarks
11-5.1	Fourier number <heat transfer>	*Fo*	relation between heat conduction rate and the rate of thermal energy storage in a body for conductive heat transfer into a body, expressed by $Fo = \frac{\alpha t}{l^2}$; where α is thermal diffusivity (ISO 80000-5), t is time (ISO 80000-3), and l is characteristic length (ISO 80000-3)	The characteristic length *l* of the body is often defined as the quotient of the body's volume and its heated surface. Sometimes the reciprocal of this number is wrongly used.
11-5.2	Péclet number <heat transfer>	*Pe*	relation between convective heat transfer rate and conductive heat transfer rate, expressed by $Pe = vl/\alpha$; where v is speed (ISO 80000-3), l is length (ISO 80000-3) in the direction of heat transfer, and α is thermal diffusivity (ISO 80000-5)	The thermal Péclet number is also given by $Pe = Re \cdot Pr$; where Re is the Reynolds number (item 11-4.1), and Pr is the Prandtl number (item 11-7.1). Compare with item 11-6.2, Péclet number for mass transfer.
11-5.3	Rayleigh number	*Ra*	relation between buoyancy forces due to thermal expansion and viscous forces in free convection in buoyancy driven flow near a heated surface perpendicular to the gravity force, expressed by $Ra = \frac{l^3 g \alpha_V \Delta T}{\nu \alpha}$; where l is distance (ISO 80000-3) from the wall, g is acceleration of free fall (ISO 80000-3), α_V is cubic expansion coefficient (ISO 80000-5) of the fluid, ΔT is difference of thermodynamic temperature (ISO 80000-5) between surface of the wall and the fluid far away from the wall, ν is kinematic viscosity (ISO 80000-4) of the fluid, and α is thermal diffusivity (ISO 80000-5) of the fluid	The Rayleigh number is also given by $Ra = Gr \cdot Pr$; where Gr is the Grashof number (item 11-4.4), and Pr is the Prandtl number (item 11-7.1).

Table 2 *(continued)*

No.	Name	Symbol	Definition	Remarks
11-5.4	Froude number <heat transfer>	Fr^*	quotient of gravitational forces and thermodiffusion forces for heat transfer in forced convection of fluids, expressed by $Fr^* = \frac{gl^3}{\alpha^2}$; where g is acceleration of free fall (ISO 80000-3), l is characteristic length (ISO 80000-3), and α is thermal diffusivity (ISO 80000-5)	
11-5.5	Nusselt number <heat transfer>	Nu	relation between the internal thermal resistance of a body and its surface thermal resistance in a body transferring heat from a surface into its interior or vice versa, expressed by $Nu = Kl/\lambda = Kl/(\alpha\rho c_p)$; where K is coefficient of heat transfer (ISO 80000-5) through the surface, l is length (ISO 80000-3) of the body in direction of heat flow, λ is thermal conductivity (ISO 80000-5) of the surface, α is thermal diffusivity (ISO 80000-5), ρ is mass density (ISO 80000-4), and c_p is specific heat capacity at constant pressure (ISO 80000-5)	The body under consideration can be a solid body, a fluid, or their combination, and additional heat transfer due to convective motion can occur. In case of merely conductive heat transfer especially in a solid body, the "Biot number for heat transfer" (item 11-5.6) is used.
11-5.6	Biot number <heat transfer>	Bi	special case of the Nusselt number for heat transfer (item 11-5.5) in case of conductive heat transfer in a solid body, expressed by $Bi = Kl/\lambda$; where K is coefficient of heat transfer (ISO 80000-5) through the surface, l is characteristic length (ISO 80000-3), and λ is thermal conductivity (ISO 80000-5) of the body	The characteristic length is commonly defined as the volume of the body divided by its surface area.

Table 2 *(continued)*

No.	Name	Symbol	Definition	Remarks
11-5.7	Stanton number <heat transfer>	St	relation between heat transfer into a fluid from a surface and its heat transfer by convection, expressed by $St = K / (\rho v c_p)$; where K is coefficient of heat transfer (ISO 80000-5) through the surface, ρ is mass density (ISO 80000-4), v is speed (ISO 80000-3), and c_p is specific heat capacity at constant pressure (ISO 80000-5) of the fluid	The Stanton number is also given by $St = Nu/(Re \cdot Pr) = Nu/Pe$; where Nu is Nusselt number for heat transfer (item 11-5.5), Re is the Reynolds number (item 11-4.1), Pr is the Prandtl number (item 11-7.1), and Pe is the Péclet number (item 11-5.2). Sometimes this quantity is called Margoulis number, symbol *Ms* or *Mg*.
11-5.8	j-factor <heat transfer>; heat transfer factor; Colburn number	j, Co, Jq	relation between heat transfer and mass transfer in a fluid, expressed by $j = \frac{K}{c_p \rho v} \left(\frac{c_p \eta}{\lambda} \right)^{2/3}$; where K is coefficient of heat transfer (ISO 80000-5), c_p is specific heat capacity at constant pressure (ISO 80000-5), ρ is mass density (ISO 80000-4), v is speed (ISO 80000-3), η is dynamic viscosity (ISO 80000-4), and λ is thermal conductivity (ISO 80000-5)	The heat transfer factor is also given by $j = St \cdot Pr^{2/3}$; where St is the Stanton number for heat transfer (item 11-5.7), and Pr is the Prandtl number (item 11-7.1). See also mass transfer factor (item 11-6.7).
11-5.9	Bejan number <heat transfer>	Be_1	quotient of mechanical work and frictional and thermal diffusion energy losses for a forced flow, expressed by $Be_1 = \frac{\Delta p l^2}{\eta \alpha}$; where Δp is drop of pressure (ISO 80000-4) along a pipe, l is length (ISO 80000-3) of the pipe, η is dynamic viscosity (ISO 80000-4), and α is thermal diffusivity (ISO 80000-5)	

Table 2 *(continued)*

No.	Name	Symbol	Definition	Remarks
11-5.10	Bejan number <entropy>	Be_S	efficiency of heat transfer by a fluid, expressed by $Be_S = \frac{S(\Delta T)}{S(\Delta T)+S(\Delta p)}$; where $S(\Delta T)$ is entropy generation contributed by heat transfer, and $S(\Delta p)$ is entropy generation contributed by fluid friction	
11-5.11	Stefan number <phase transition>	Ste, Stf	relation between heat content and latent heat content in a binary mixture undergoing a phase transition, expressed by $Ste = c_p \Delta T / Q$; where c_p is specific heat capacity at constant pressure (ISO 80000-5), ΔT is difference of thermodynamic temperature T (ISO 80000-5) between the phases, and Q is quotient of latent heat of phase transition (ISO 80000-5) and mass (ISO 80000-4)	
11-5.12	Brinkman number	Br, N_{Br}	relation between heat produced by viscosity and heat conducted from a wall adjacent to a fluid moving relative to it, expressed by $Br = \eta v^2 / (\lambda \Delta T)$; where η is dynamic viscosity (ISO 80000-4), v is characteristic speed (ISO 80000-3), λ is thermal conductivity (ISO 80000-5), and $\Delta T = T_W - T_0$ is difference of thermodynamic temperature T (ISO 80000-5), where T_0 is bulk fluid temperature, and T_W is wall temperature	

Table 2 *(continued)*

No.	Name	Symbol	Definition	Remarks
11-5.13	Clausius number	Cl	relation between energy transfer associated with fluid momentum and energy transfer by thermal conduction in forced heating, expressed by $Cl = v^3 l \rho / (\lambda \Delta T)$; where v is speed (ISO 80000-3), l is length (ISO 80000-3) of the path of energy transfer, ρ is mass density (ISO 80000-4), λ is thermal conductivity (ISO 80000-5), and ΔT is difference of thermodynamic temperature T (ISO 80000-5) along length l	
11-5.14	Carnot number	Ca	theoretical maximum efficiency (ISO 80000-5) of a Carnot cycle operating between temperature reservoirs $Ca = (T_2 - T_1)/T_2$; where T is thermodynamic temperature (ISO 80000-5), and T_2, T_1 are the thermodynamic temperatures of a heat source and a heat sink, respectively	
11-5.15	Eckert number; Dulong number	Ec	relation between the kinetic energy of a flow and its enthalpy change in fluid dynamics exhibiting dissipation, expressed by $Ec = v^2 / (c_p \Delta T)$; where v is characteristic speed (ISO 80000-3), c_p is specific heat capacity at constant pressure (ISO 80000-5) of the flow, and ΔT is difference of thermodynamic temperature T (ISO 80000-5) due to dissipation (by friction)	

Table 2 *(continued)*

No.	Name	Symbol	Definition	Remarks
11-5.16	Graetz number <heat transfer>	*Gz*	relation between heat transferred by convection and heat transferred by conduction in a laminar flow in a pipe, expressed by $Gz = \frac{vd^2}{\alpha l}$; where v is speed (ISO 80000-3) of the fluid, d is diameter (ISO 80000-3) of the pipe, α is thermal diffusivity (ISO 80000-5) of the fluid, and l is length (ISO 80000-3) of the pipe	
11-5.17	heat transfer number	K_Q	relation between heat transferred by a flow and its kinetic energy, expressed by $K_Q = \Phi / (v^3 l^2 \rho)$; where Φ is heat flow rate (ISO 80000-5), v is characteristic speed (ISO 80000-3), l is characteristic length (ISO 80000-3), and ρ is mass density (ISO 80000-4)	
11-5.18	Pomerantsev number <heat transfer>	*Po*, *Pov*	relation between heat generated in a body and conducted heat in the body, expressed by $Po = Q_m l^2 / (\lambda \Delta T)$; where Q_m is (constant) volumic heat generation rate, l is characteristic length (ISO 80000-3), λ is thermal conductivity (ISO 80000-5), and $\Delta T = T_m - T_0$ is difference of thermodynamic temperature (ISO 80000-5) between that of the medium (T_m) and the initial temperature of the body (T_0)	Similar numbers are known for areic, lineic and point sources of heat, each with decreasing power of length *l* respectively.

Table 2 *(continued)*

No.	Name	Symbol	Definition	Remarks
11-5.19	Boltzmann number	*Bz*, *Bol*, *Bo*	relation between convective heat and radiant heat for a fluid in a channel, expressed by $Bz = \rho v c_p / (\varepsilon \sigma T^3)$; where ρ is mass density (ISO 80000-4) of the fluid, v is characteristic speed (ISO 80000-3) of the fluid, c_p is specific heat capacity at constant pressure (ISO 80000-5), ε is emissivity (ISO 80000-7), σ is the Stefan-Boltzmann constant (ISO 80000-7), and T is thermodynamic temperature (ISO 80000-5)	
11-5.20	Stark number DEPRECATED: Stefan number DEPRECATED: Biot radiation number	*Sk*	relation between radiant heat and conductive heat multiplied by the relative temperature difference for a body, expressed by $Sk = \varepsilon \sigma T^3 l / \lambda$; where ε is emissivity (ISO 80000-7) of the surface, σ is the Stefan-Boltzmann constant (ISO 80000-7), T is thermodynamic temperature (ISO 80000-5), l is characteristic length (ISO 80000-3), and λ is thermal conductivity (ISO 80000-5)	The relative temperature difference is defined by $\frac{\Delta T}{T}$; where $\Delta T = T_s - T_l$ is the difference of the temperature at the surface, T_s, and the temperature at a layer at a distance l from the surface, T_l. Sometimes this characteristic number is wrongly defined without the factor ε.

6 Transfer of matter in a binary mixture

Table 3 gives the names, symbols and definitions of characteristic numbers used to characterize processes in which transfer of matter in a binary mixture plays a predominant role. Transfer of matter in a binary mixture is accomplished in general by diffusion with its coefficient D (ISO 80000-9). The two components can move with speed v relative to each other, and the movement of one component can be influenced by the other one.

Table 3 — Characteristic numbers for transfer of matter in a binary mixture

No.	Name	Symbol	Definition	Remarks
11-6.1	Fourier number <mass transfer>	Fo^*	relation between diffusive mass transfer within a given duration and mass storage rate in transient mass transfer, expressed by $Fo^* = \frac{Dt}{l^2}$; where D is diffusion coefficient (ISO 80000-9), t is duration (ISO 80000-3) of observation, and l is length (ISO 80000-3) of transfer	The Fourier number for mass transfer is also given by $Fo^* = Fo/Le$; where Fo is the Fourier number for heat transfer (item 11-5.1), and Le is the Lewis number (item 11-7.3). See also the Fourier number for heat transfer (item 11-5.1).
11-6.2	Péclet number <mass transfer>; Bodenstein number <mass transfer>	Pe^*, Bd, Bod	relation between advective mass transfer rate and longitudinal diffusive mass transfer rate for mass transfer in reactors, expressed by $Pe^* = vl/D$; where v is speed (ISO 80000-3), l is characteristic length (ISO 80000-3), and D is diffusion coefficient (ISO 80000-9)	The Péclet number for mass transfer is also given by $Pe^* = Pe \cdot Le = Re \cdot Sc$; where Pe is the Péclet number for heat transfer, Le is the Lewis number (item 11-7.3), Re is the Reynolds number (item 11-4.1), and Sc is the Schmidt number (item 11-7.2). Compare with item 11-5.2, the Péclet number for heat transfer.
11-6.3	Grashof number <mass transfer>	Gr^*	relation between buoyancy forces and viscous forces in natural convection of fluids, expressed by $Gr^* = l^3 g \beta \Delta x / \nu^2$; where l is characteristic length (ISO 80000-3), g is acceleration of free fall (ISO 80000-3), $\beta = -(1/\rho)(\partial\rho/\partial x)_{T,p}$, where ρ is mass density (ISO 80000-4) of the fluid, and x is amount-of-substance fraction (ISO 80000-9), Δx is difference of amount-of-substance fraction (ISO 80000-9) along length l, and ν is kinematic viscosity (ISO 80000-4)	Instead of "amount-of-substance fraction" the "amount-of-substance concentration" (ISO 80000-9) is used also. Compare with item 11-4.4, the Grashof number.

Table 3 *(continued)*

No.	Name	Symbol	Definition	Remarks
11-6.4	Nusselt number <mass transfer>	Nu^*	relation between mass flux at an interface and specific flux by pure molecular diffusion in a layer of thickness *l* for mass transfer at the boundary of a fluid, expressed by $Nu^* = k' l / (\rho D)$; where k' is mass flux density q_m / A through the surface, where q_m is mass flow rate (ISO 80000-4), and A is area (ISO 80000-3), l is thickness (ISO 80000-3), ρ is mass density (ISO 80000-4) of the fluid, and D is diffusion coefficient (ISO 80000-9)	Sometimes this quantity is called the Sherwood number, *Sh*. Compare with item 11-5.5, Nusselt number for heat transfer.
11-6.5	Stanton number <mass transfer>	St^*	relation between mass transfer perpendicular to the surface of a fluid flow and mass transfer parallel to the surface in a free surface flow, expressed by $St^* = k' / (\rho v)$; where k' is mass flux density q_m / A through the surface, where q_m is mass flow rate (ISO 80000-4), and A is area (ISO 80000-3), ρ is mass density (ISO 80000-4), and v is speed (ISO 80000-3)	The Stanton number for mass transfer is also given by $St^* = Nu^* / Pe^*$; where Nu^* is the Nusselt number for mass transfer (item 11-6.4), and Pe^* is the Péclet number for mass transfer (item 11-6.2). Compare with item 11-5.7, the Stanton number for heat transfer.
11-6.6	Graetz number <mass transfer>	Gz^*	quotient of advective mass transfer rate and radial diffusive mass transfer rate for mass transfer in pipes, expressed by $Gz^* = \frac{vd}{D} = \frac{d}{l} Pe^*$; where v is characteristic speed (ISO 80000-3) of the fluid, d is hydraulic diameter (ISO 80000-3) of the pipe, D is diffusion coefficient (ISO 80000-9), l is length (ISO 80000-3) of the pipe, and Pe^* is the Péclet number for mass transfer (item 11-6.2)	

Table 3 *(continued)*

No.	Name	Symbol	Definition	Remarks
11-6.7	mass transfer factor; j-factor <mass transfer>	j^*	relation between mass transfer perpendicular to the surface of a fluid and mass transfer parallel to the surface in an open flow of fluids, expressed by $j^* = \frac{k}{v}\left(\frac{\nu}{D}\right)^{2/3}$; where k is the mass transfer coefficient through the surface, $k = k'/\rho$, where ρ is mass density (ISO 80000-4), k' is mass flux density q_m/A through the surface, where q_m is mass flow rate (ISO 80000-4), and A is area (ISO 80000-3), v is speed (ISO 80000-3), ν is kinematic viscosity (ISO 80000-4), and D is diffusion coefficient (ISO 80000-9)	The mass transfer factor is also given by $j_m = j^* = St^* \cdot Sc^{2/3}$; where St^* is the Stanton number for mass transfer (item 11-6.5), and Sc is the Schmidt number (item 11-7.2). See also heat transfer factor (item 11-5.17).
11-6.8	Atwood number	At	scaled density difference of heavier and lighter fluids, expressed by $At = \frac{\rho_1 - \rho_2}{\rho_1 + \rho_2}$; where ρ_1 is density of heavier fluid, and ρ_2 is density of lighter fluid	The Atwood number is used in the study of hydrodynamic instabilities in density stratified flows.

Table 3 *(continued)*

No.	Name	Symbol	Definition	Remarks
11-6.9	Biot number <mass transfer>	Bi^*	relation between mass transfer rate at the interface and mass transfer rate in the interior of a body, expressed by $Bi^* = kl/D_{int}$; where k is the mass transfer coefficient through the surface, $k = k'/\rho$, where ρ is mass density (ISO 80000-4), k' is mass flux density q_m/A through the surface, where q_m is mass flow rate (ISO 80000-4), and A is area (ISO 80000-3), l is thickness (ISO 80000-3) of layer, and D_{int} is diffusion coefficient (ISO 80000-9) at the interface	
11-6.10	Morton number	Mo	quotient of gravitational forces and viscous forces for gas bubbles in a liquid, or liquid drops in a gas, expressed by $Mo = \frac{g\eta^4}{\rho\gamma^3}\left(\frac{\rho_b}{\rho} - 1\right)$; where g is acceleration of free fall (ISO 80000-3), η is dynamic viscosity (ISO 80000-4) of the surrounding fluid, ρ is mass density (ISO 80000-4) of the surrounding fluid, γ is surface tension (ISO 80000-4) of the interface, and ρ_b is mass density (ISO 80000-4) of the bubble or drop	The Morton number is used to determine the shape of bubbles or drops. The Morton number is also given by $Mo = We^3 Fr^{-2} Re^{-4}$; where We is the Weber number (item 11-4.5), Fr is the Froude number (item 11-4.3), and Re is the Reynolds number (item 11-4.1).

Table 3 *(continued)*

No.	Name	Symbol	Definition	Remarks
11-6.11	Bond number; Eötvös number	*Bo*, *Eo*	quotient of inertial force and capillary force for gas bubbles or liquid drops in a fluid, expressed by $Bo = \frac{a}{\gamma} \rho l^2 \left(\frac{\rho_b}{\rho} - 1 \right)$; where a is the acceleration of the body (ISO 80000-3), mostly acceleration of free fall, g (ISO 80000-3), γ is surface tension (ISO 80000-4) of the interface, ρ is density (ISO 80000-4) of the medium, l is characteristic length (ISO 80000-3) (radius of a drop or radius of a capillary tube), and ρ_b is mass density (ISO 80000-4) of the drop or bubble	In the case of gravity $a = g$ acceleration of free fall (ISO 80000-3), the name Eötvös number is mostly used. The Bond number is also given by $Bo = We / Fr$; where We is the Weber number (item 11-4.5), and Fr is the Froude number (item11-4.3). The Bond number is also used for capillary action driven by buoyancy.
11-6.12	Archimedes number	*Ar*	quotient of buoyancy forces and viscous forces in fluids motion due to density differences for a body in a fluid, expressed by $Ar = \frac{g l^3}{\nu^2} \left(\frac{\rho_b}{\rho} - 1 \right)$; where g is acceleration of free fall (ISO 80000-3), l is characteristic length (ISO 80000-3) of the body, ν is kinematic viscosity (ISO 80000-4) of the fluid, ρ_b is mass density (ISO 80000-4) of the body, and ρ is mass density (ISO 80000-4) of the fluid	In this definition, the body can be replaced by an immiscible fluid. See also Stokes number <rotameter> (item 11-4.34).
11-6.13	expansion number	*Ex*	quotient of buoyancy force and inertial force in moving fluids due to density differences for gas bubbles rising in a liquid, expressed by $Ex = \frac{gd}{v^2} \left(1 - \frac{\rho_b}{\rho} \right)$; where g is acceleration of free fall (ISO 80000-3), d is diameter (ISO 80000-3) of bubbles, v is speed (ISO 80000-3) of bubbles, ρ_b is mass density (ISO 80000-4) of bubbles, and ρ is mass density (ISO 80000-4) of the liquid	

Table 3 *(continued)*

No.	Name	Symbol	Definition	Remarks
11-6.14	Marangoni number	*Mg*, *Mar*	quotient of heat transferred by Marangoni convection and heat transferred by thermal diffusivity in thermo-capillary convection of liquid films on a free surface, expressed by $Mg = l\frac{\Delta T}{\eta a}\left(\frac{\mathrm{d}\gamma}{\mathrm{d}T}\right)$; where l is characteristic thickness (ISO 80000-3) of the film, ΔT is difference of thermodynamic temperature T (ISO 80000-5) between surface and outer surface of the film, η is dynamic viscosity (ISO 80000-4) of the liquid, a is thermal diffusivity (ISO 80000-5) of the liquid, and γ is surface tension (ISO 80000-4) of the film	The Marangoni convection is free surface flow due to different surface tensions caused by a temperature gradient. This quantity is sometimes called Thompson number.
11-6.15	Lockhart-Martinelli parameter	*Lp*	quotient of mass flow rates multiplied by the square root of density in a two-phase flow, expressed by $Lp = \frac{\dot{m}_\mathrm{l}}{\dot{m}_\mathrm{g}}\sqrt{\frac{\rho_\mathrm{g}}{\rho_\mathrm{l}}}$; where $\dot{m}_\mathrm{l} = q_\mathrm{m}$ is liquid phase mass flow rate (ISO 80000-4), $\dot{m}_\mathrm{g}$ is gas phase mass flow rate, ρ_g is gas density (ISO 80000-4), and ρ_l is liquid density	The Lockhart-Martinelli parameter is used, for example, in boiling or condensing.
11-6.16	Bejan number <mass transfer>	Be^*, Be_2	quotient of mechanical work and frictional and diffusion energy loss in viscous flow of fluids in pipes, expressed by $Be^* = \frac{\Delta p\, l^2}{\eta D}$; where Δp is drop of pressure (ISO 80000-4) along a pipe or channel, l is length (ISO 80000-3) of channel, η is dynamic viscosity (ISO 80000-4) of the fluid, and D is diffusion coefficient (ISO 80000-9), mass diffusivity	A similar quantity exists for heat transfer (item 11-5.9).

Table 3 *(continued)*

No.	Name	Symbol	Definition	Remarks
11-6.17	cavitation number	*Ca*, *Cn*	quotient of the excess of local static head over vapour pressure head and velocity head for fast flow in liquids, expressed by $Ca = \frac{p - p_v}{\rho v^2 / 2}$; where p is local static pressure (ISO 80000-4), p_v is vapour pressure (ISO 80000-4) of the fluid, ρ is mass density (ISO 80000-4) of the fluid, and v is characteristic speed (ISO 80000-3) of the flow	The cavitation number represents the ratio of the excess of local static head over vapour pressure head to velocity head.
11-6.18	absorption number	*Ab*	relation between mass flow rate and surface area for gas absorption at wetted walls, expressed by $Ab = k\sqrt{\frac{ld}{Dq_V}}$; where k is the mass transfer coefficient through the surface, $k = k'/\rho$, where ρ is mass density (ISO 80000-4), and k' is mass flux density through the surface, $k' = q_m/A$, where q_m is mass flow rate (ISO 80000-4), and A is area (ISO 80000-3), l is length (ISO 80000-3) of wetted surface, d is thickness (ISO 80000-3) of liquid film, D is diffusion coefficient (ISO 80000-9), and q_V is volume flow rate (ISO 80000-4) per wetted perimeter	

Table 3 *(continued)*

No.	Name	Symbol	Definition	Remarks
11-6.19	capillary number	Ca	quotient of gravitational forces and capillary forces for fluids in narrow pipes, expressed by $Ca = d^2 \rho g / \gamma$; where d is diameter (ISO 80000-3) of the pipe, ρ is mass density (ISO 80000-4) of the fluid, g is acceleration of free fall (ISO 80000-3), and γ is surface tension (ISO 80000-4) of the fluid	
11-6.20	dynamic capillary number	Ca^*, Cn	quotient of viscous force and capillary force acting across an interface between a liquid and a gas, or between two immiscible liquids for a flow of fluid influenced by interfacial tension, expressed by $Ca^* = \eta v / \gamma$; where η is dynamic viscosity (ISO 80000-4) of the fluid, v is characteristic speed (ISO 80000-3), and γ is surface or interfacial tension (ISO 80000-4)	The dynamic capillary number is also given by the quotient of the Weber number and the Reynolds number.

7 Constants of matter

Table 4 gives the names, symbols and definitions of some constants of matter, concerning mechanic, electric and thermodynamic properties of material, as well as their relationships. Some of the most widely known are not listed in the table because they are given in other parts of the ISO 80000 series, e.g. the ratio of the specific heat capacities, γ (ISO 80000-5), or the emissivity, ε (ISO 80000-7).

Table 4 — Constants of matter

No.	Name	Symbol	Definition	Remarks
11-7.1	Prandtl number	Pr	quotient of kinematic viscosity and thermal diffusivity for a fluid, expressed by $Pr = \nu / a$; where ν is kinematic viscosity (ISO 80000-4), and a is thermal diffusivity (ISO 80000-5)	The Prandtl number also represents the quotient of heat produced by viscosity and heat transferred by thermal diffusivity. The mass transfer analogue of the Prandtl number is the Schmidt number (item 11-7.2). The Prandtl number is also given by $Pr = Pe/Re$; where Pe is the Péclet number (item 11-5.2), and Re is the Reynolds number (item 11-4.1).
11-7.2	Schmidt number DEPRECATED: Colburn number	Sc	quotient of kinematic viscosity and diffusion coefficient for a fluid, expressed by $Sc = \nu / D$; where ν is kinematic viscosity (ISO 80000-4), and D is diffusion coefficient (ISO 80000-9)	The heat transfer analogue of the Schmidt number is the Prandtl number (item 11-7.1).
11-7.3	Lewis number	Le	quotient of thermal diffusivity and diffusion coefficient for heat transfer in a fluid, expressed by $Le = a / D$; where a is thermal diffusivity (ISO 80000-5), and D is diffusion coefficient (ISO 80000-9)	The Lewis number is also given by $Le = Sc / Pr$; where Sc is the Schmidt number (item 11-7.2), and Pr is the Prandtl number (item 11-7.1). Compare with item 11-5.2. The Lewis number is sometimes defined as reciprocal of this quantity.
11-7.4	Ohnesorge number	Oh	relation between viscous force and the square root of the product of inertia force and capillary force for atomization of liquids, expressed by $Oh = \frac{\eta}{\sqrt{\gamma \rho l}}$; where η is dynamic viscosity (ISO 80000-4), γ is surface tension (ISO 80000-4), ρ is mass density (ISO 80000-4), and l is characteristic length (ISO 80000-3)	The Ohnesorge number is also given by $Oh = \sqrt{We} / Re$; where We is the Weber number (item 11-4.5), and Re is the Reynolds number (item 11-4.1). See also Laplace number (item 11-4.37). The characteristic length typically is the drop diameter.

Table 4 *(continued)*

No.	Name	Symbol	Definition	Remarks
11-7.5	Cauchy number; aeroelasticity parameter	Cy	relation between inertia forces and compression forces in compressible fluids, expressed by $Cy = \rho v^2 / K$; where ρ is mass density (ISO 80000-4), v is speed (ISO 80000-3), and K is modulus of compression, bulk modulus (ISO 80000-4)	
11-7.6	Hooke number	Ho_2	relation between inertia forces and linear stress forces in elastic fluids, expressed by $Ho_2 = \rho v^2 / E$; where ρ is mass density (ISO 80000-4), v is speed (ISO 80000-3), and E is modulus of elasticity (ISO 80000-4)	
11-7.7	Weissenberg number	Wi	product of time derivative of shear rate and relaxation time in viscoelastic flows, expressed by $Wi = \dot{\gamma} t_r$; where $\dot{\gamma}$ is time derivative of shear strain (ISO 80000-4), and t_r is relaxation time (ISO 80000-12)	The Weissenberg number represents the relative importance of viscous forces when compared to elastic forces. The time derivative of shear strain is sometimes called the shear rate.
11-7.8	Deborah number	De	quotient of relaxation time of viscoelastic fluids and observation duration in rheology of viscoelastic fluids, expressed by $De = t_c / t_p$; where t_c is stress relaxation time, and t_p is observation duration (ISO 80000-3)	The stress relaxation time is sometimes called the Maxwell relaxation time.

Table 4 *(continued)*

No.	Name	Symbol	Definition	Remarks
11-7.9	Lorentz number	*Lo*	quotient of electrical conductivity and thermal conductivity, expressed by $Lo = \frac{\sigma(\Delta U)^2}{\lambda \Delta T}$; where σ is electrical conductivity (IEC 80000-6), ΔU is difference of voltage U (ISO 80000-6) between two reference points, λ is thermal conductivity (ISO 80000-5), and ΔT is difference in thermodynamic temperature T (ISO 80000-5) between the reference points	
11-7.10	compressibility number	*Z*	quotient of isothermal compressibility (ISO 80000-5) of a gas and that of an ideal gas, expressed by $Z = \frac{p}{\rho R_S T}$; where p is pressure (ISO 80000-4), ρ is mass density (ISO 80000-4), R_s is specific gas constant (ISO 80000-5), and T is thermodynamic temperature (ISO 80000-5)	

8 Magnetohydrodynamics

Table 5 gives the names, symbols and definitions of characteristic numbers found in magnetohydrodynamics (MHD). MHD is concerned with the dynamics of electrically conducting fluids, which are characterized by material constants such as mass density (ISO 80000-4), magnetic permeability (IEC 80000-6) and electrical conductivity (IEC 80000-6), and which interact with external fields like magnetic flux density (IEC 80000-6).

Table 5 — Characteristic numbers in magnetohydrodynamics

No.	Name	Symbol	Definition	Remarks
11-8.1	Reynolds magnetic number	*Rm*	relation between inertial force and magneto-dynamic viscous force in an electrically conducting fluid, expressed by $Rm = vl\mu\sigma = vl/\nu_m$; where v is speed (ISO 80000-3) of the fluid, l is characteristic length (ISO 80000-3), μ is magnetic permeability (IEC 80000-6), σ is electrical conductivity (IEC 80000-6), and $\nu_m = 1/(\mu\sigma)$ is magnetic viscosity (magnetic diffusivity)	This number is also called magnetic Reynolds number. The Reynolds magnetic number is also given by $Rm = Re \cdot Pr_m$; where Re is the Reynolds number (item 11-4.1), and Pr_m is the Prandtl magnetic number (item 11-8.10).
11-8.2	Batchelor number	*Bt*	relation between inertia and magneto-dynamic diffusion in an electrically conducting liquid, expressed by $Bt = vl\sigma\mu/(\varepsilon_r\mu_r)$; where v is speed (ISO 80000-3), l is characteristic length (ISO 80000-3), σ is electrical conductivity (IEC 80000-6), μ is magnetic permeability (IEC 80000-6), ε_r is relative permittivity (IEC 80000-6), and μ_r is relative permeability (IEC 80000-6)	
11-8.3	Nusselt electric number	*Ne*	relation between convective current and diffusive current of ions in electrochemistry, expressed by $Ne = vl/D^*$; where v is speed (ISO 80000-3), l is characteristic length (ISO 80000-3), and $D^* = (D^+ + D^-)/2$; where D^+, D^- are diffusion coefficients (ISO 80000-9) of positive or negative ions respectively	This number is also called electric Nusselt number. Sometimes this quantity is called the Reynolds electric number.

Table 5 *(continued)*

No.	Name	Symbol	Definition	Remarks
11-8.4	Alfvén number; Mach magnetic number; Kárman number	*Al*	relation between speed of a plasma and the Alfvén wave speed, expressed by $Al = \frac{v}{B/\sqrt{\rho\mu}}$; where v is speed (ISO 80000-3), B is magnetic flux density (IEC 80000-6), ρ is mass density (ISO 80000-4), and μ is magnetic permeability (IEC 80000-6)	Often, the inverse of this number is wrongly used. The name "Alfvén Mach number" is used in investigations on the solar wind. The quantity $v_A = B/\sqrt{\rho\mu}$ is called Alfvén wave speed, where B is magnetic flux density (IEC 80000-6), ρ is mass density (ISO 80000-4), and μ is magnetic permeability (IEC 80000-6).
11-8.5	Hartmann number	*Ha*	relation between magnetically induced stress and hydrodynamic shear stress in an electrically conducting fluid, expressed by $Ha = Bl\sqrt{(\sigma/\eta)}$; where B is magnetic flux density (IEC 80000-6), l is characteristic length (ISO 80000-3), σ is electrical conductivity (IEC 80000-6), and η is dynamic viscosity (ISO 80000-4)	The Hartmann number represents also the ratio of magnetic force to viscous force.
11-8.6	Cowling number <magnetism>; Euler magnetic number	*Co*	quotient of magnetic and kinematic energy density in a plasma, expressed by $Co = B^2/(\mu \rho v^2)$; where B is magnetic flux density (IEC 80000-6), μ is magnetic permeability (IEC 80000-6), ρ is mass density (ISO 80000-4), and v is speed (ISO 80000-3)	The Cowling number also represents the ratio of magnetic to dynamic pressure. This quantity is equal to the square of the inverse of the Alfvén number. This quantity is often called the second Cowling number, Co_2. The first Cowling number is then defined as $Co_1 = Co \cdot Rm$; where *Rm* is the Reynolds magnetic number (item 11-8.1).

Table 5 *(continued)*

No.	Name	Symbol	Definition	Remarks
11-8.7	Stuart electrical number	Se	quotient of electric energy density and kinematic energy density in a plasma, expressed by $Se = \varepsilon E^2 / (\rho v^2)$; where ε is electric permittivity (IEC 80000-6), E is electric field strength (IEC 80000-6), ρ is mass density (ISO 80000-4), and v is speed (ISO 80000-3)	The Stuart electrical number is the electrical counterpart of the Cowling number (item 11-8.6).
11-8.8	magnetic pressure number	N_{mp}	quotient of gas pressure and magnetic pressure in a gas or plasma, expressed by $N_{mp} = p \frac{2\mu}{B^2}$; where p is pressure (ISO 80000-4), μ is magnetic permeability (IEC 80000-6), and B is magnetic flux density (IEC 80000-6)	The quantity $p_m = B^2 / (2\mu)$ is called magnetic pressure, where B is magnetic flux density (IEC 80000-6), and μ is magnetic permeability (IEC 80000-6).
11-8.9	Chandrasekhar number	Q, Ch	quotient of Lorentz force and viscous force in magnetic convection in a fluid, expressed by $Q = (Bl)^2 \sigma / \rho\nu$; where B is magnetic flux density (IEC 80000-6), l is characteristic length (ISO 80000-3), a length scale of the system, σ is electrical conductivity (IEC 80000-6), ρ is mass density (ISO 80000-4), and ν is kinematic viscosity (ISO 80000-4)	The Chandrasekhar number is also given by $Q = Ha^2$ where Ha is the Hartmann number (item 11-8.5).