Mechanics of Fluids

SECOND EDITION SI UNITS

A. C. Walshaw and
D. A. Jobson

Second Edition
In SI Units

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Longman

LONGMAN GROUP LIMITED, LONDON
Associated companies, branches and representatives throughout the world

FIRST PUBLISHED 1962
SECOND IMPRESSION 1965
THIRD IMPRESSION 1967

SECOND EDITION 1972

ISBN: 0582 44485 3 Cased
ISBN: 0582 44494 2 Paper

TYPESET BY ETA SERVICES (TYPESETTERS) LTD AND PRINTED IN GREAT BRITAIN BY HAZELL, WATSON & VINEY LTD.

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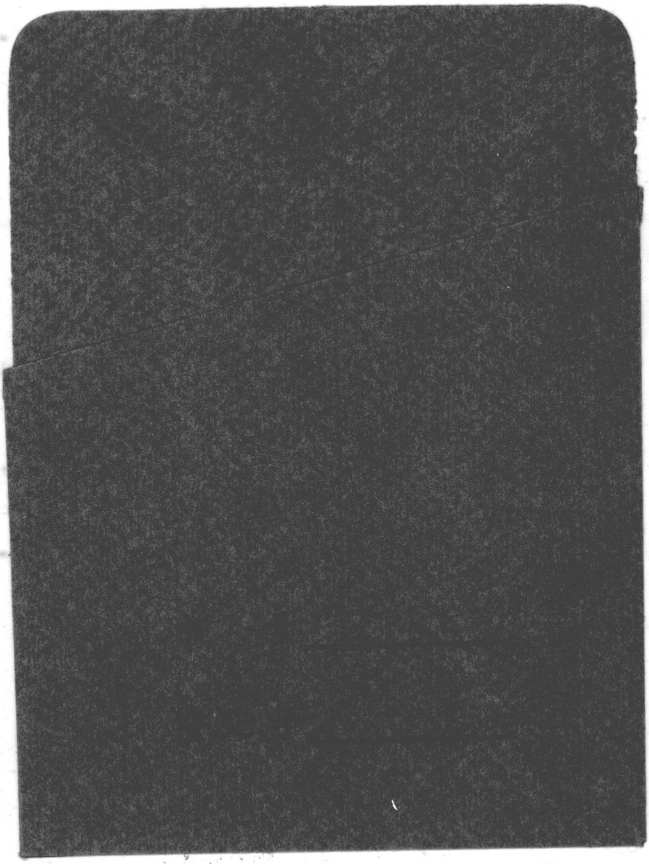
Thermodynamics for Engineers

SI Units and Worked Examples



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Preface

In this edition SI units have been used throughout, and new material has replaced less important sections and problems of the first edition. The book is primarily for those studying for examinations leading to Engineering Degrees and Diplomas, Higher National Diplomas and Certificates, and Examinations of Professional Institutions.

It aims at presenting a straightforward and modern approach to the subject of Fluid Mechanics. Analysis and development of fundamental formulae have been kept as simple as possible. Worked examples are included in the text to illustrate the applications of fundamental principles in design and practical problems. In order to get a thorough grasp of the subject however, it is essential that students should supplement a study of the text and worked examples by working out a selection of the exercises included at the ends of the chapters.

There are few pieces of modern engineering plant or machinery which do not to some extent depend on a measure of understanding of the Mechanics of Fluids for their successful operation or control. In many cases the process of fluid motion is fundamental. Consequently the flow of fluids through prime movers such as water turbines, gas turbines and jet engines has become increasingly important as, also, has the flow of liquids and gases through pumps and compressors. The development of the aeroplane, and the need to develop rockets, missiles, torpedoes, submarines and speedy ships has compelled an intense and thorough study of the motion of fluids generally—gaseous and liquid—relative to solid bodies. Many empirical formulae of the past have now been replaced by rational ones as a result of analysis by the Method of Dimensions, which reveals the non-dimensional groups or parameters by means of which graphs may be plotted in the most condensed and yet most general form.

This book is intended to serve in introducing and assisting students in their early studies of these things.

A. C. W.
D. A. J.

Key to main use of symbols

Symbols for physical quantities are usually single letters printed in italics or sloping type. Two-letter symbols (from proper names) are, however, used to represent dimensionless groups of certain physical quantities (e.g. Mach number, $Ma = u/a$; Reynolds' number $Re = ud/\nu$). Such two-letter symbols can have their indivisibility stressed, if necessary, by placing them within brackets.

Symbol	*Signification*
A	Area; constant.
a	Area; linear acceleration; local speed of sound; index number; constant.
b	Breadth; index number; constant.
C	Coefficient; cycles/unit-time; capacitance; heat-capacity.
c	Constant; index number; chord length; specific heat-capacity; velocity of sound in water or speed of a wavelet.
D	Diameter; drag force or stress; draught of floating body.
d	Depth; diameter; index number; relative density (ρ/ρ_w).
E	Energy; Young's modulus.
F	Force; function of.
f	Friction coefficient; function of.
Fr	Froude number ($u/\sqrt{(gl)}$).
g	Acceleration of free fall.
g_n	International standard acceleration due to gravity (9·80665 m/s^2).
H, h	Head; enthalpy.
h_L	Head loss.
I	Moment of inertia; second moment of area; specific impulse.
i	Slope of hydraulic gradient.
J	Non-dimensional group (V/ND) for propellers.
K	Bulk modulus.
k	Radius of gyration; constant or coefficient.
L	Length; aero-dynamic force of lift.
l	Length.
M	Mass; moment or torque.
m	Mass; hydraulic mean depth; suffix meaning 'model'.
$\dot{m}$	Rate of mass flow.

Symbol	*Signification*
Ma	Mach number (u/a).
N	Rotational speed.
n	Number; index in gas law (PV^n); distance along a normal.
P, p	Pressure; wetted perimeter; power.
Q, q	Rate of volumetric flow; quantity of heat-transfer.
R	Radius; gas constant ($P = \rho RT$); force of reaction.
Re	Reynolds' number (ud/ν or $\rho ul/\eta$).
S	Surface area; distance; scale ratio.
s	Distance; slip.
T	Thrust; torque; absolute temperature; surface tension.
t	Time; customary scale-temperature (Celsius, °C).
U	Upthrust; linear velocity.
u	Linear velocity.
V	Volume; linear velocity,
v	Specific volume (V/m).
W	Load or weight; work.
X, x	Distance.
Y, y	Distance.
Z, z.	Height above a datum.
α	Angle; angular acceleration.
β	Angle.
γ	Ratio of specific heat-capacities c_p/c_v of gases.
ϵ	Eccentricity ratio; efficiency.
η	Dynamic viscosity; efficiency.
θ	Angle.
λ	Friction coefficient ($\lambda = 4f$).
μ	Coefficient of friction.
ν	Kinematic viscosity ($\nu = \eta/\rho$).
π, Π	3·1416; non-dimensional group.
ρ	Density ($\rho = m/V = 1/v$).
Σ	Sum of.
τ	Viscous shear stress; periodic time.
φ	Angle; function of.
$\dot{\varphi}$	Strain rate.
ψ	Angle; function of.
ω, Ω	Angular velocity.

The word 'specific' is restricted to the meaning 'divided by mass'—e.g. specific volume $v = V/m = 1/\rho$.

Symbols for units are printed in lower case roman (upright) type, except when a unit is derived from a proper name. A capital roman letter is then taken as the unit symbol—e.g. N (newton), K (kelvin), A (ampere), J (joule).

SI base units

Quantity	Name of unit	Unit-symbol
Length	metre	m
Mass	kilogramme	kg
Time	second	s
Thermodynamic temperature	kelvin	K
Electric current	ampere	A
Luminous intensity	candela	cd

Supplementary units

Plane angle	radian	rad
Solid angle	steradian	sr
Quantity of substance	mole	mol

Derived units and special names

			SI units
Force	newton	N	$kg\ m/s^2$
Energy	joule	J	$Nm = kg\ m^2/s^2$
Power	watt	W	$J/s = kg\ m^2/s^3$
Pressure	pascal	Pa	$N/m^2 = kg/s^2m$
Volume	litre	l	$dm^3 = 10^{-3}\ m^3$
Mass	tonne	t	$Mg = 10^3\ kg$
Time	minute	min	60 s
Dynamic viscosity	poise	P	$10^{-1}\ kg/sm$
Kinematic viscosity	stoke	St	$10^{-4}\ m^2/s$
Frequency	hertz	Hz	s^{-1}
Electrical potential	volt	V	$J/sA = kg\ m^2/s^3A$
Electrical resistance	ohm	Ω	$kg\ m^2/s^3A^2$

Multiples and sub-multiples of SI and derived units

Appropriate sizes of units can be provided by use of prefixes signifying multiples and sub-multiples of 10—there being single-letter abbreviations internationally agreed (see table on following page).
The prefix is part of the unit—i.e. the combination of a prefix and unit-symbol is considered as *one new unit-symbol*, e.g. 1 km^2 is 1 $(km)^2$, *not* 1000 m^2.

As a general rule prefixes are used in the numerator only, e.g. $MJ/dm^3 = 10^9\ J/m^3$ is less cumbersome and clearer if written GJ/m^3, as is Young's modulus $E = 207\ kN/mm^2$ if written 207 GN/m^2.

Fraction	Prefix		Multiple	Prefix	
	Name	Abbreviation		Name	Abbreviation
10^{-1}	deci	d	10	deca	da
10^{-2}	centi	c	10^2	hecto	h
10^{-3}	milli	m	10^3	kilo	k
10^{-6}	micro	μ	10^6	mega	M
10^{-9}	nano	n	10^9	giga	G
10^{-12}	pico	p	10^{12}	tera	T

Only one prefix is applied at one time to a unit-symbol, e.g. 1 megagramme is written 1 Mg, not 1 kkg. Thus, although the name 'kilogramme' has been retained for the SI unit of mass, the *single-prefix rule* is applied in that kg *is regarded as a prefixed unit*. Similarly, although 1 P = 1 dN s/m², one centipoise (1 cP) is not written as 1 cdN s/m² but as 1 mN s/m², in which it will be seen that care is needed with the 'm's'. Hence, *prefixes are printed immediately adjacent to their unit-symbols*, e.g. mN is a prefixed symbol meaning milli-newton. It must not be confused with a metre-Newton which is denoted here either by m × N or by m.N; the use of Nm instead is better in the sense that it eliminates the possible confusion.

In practice, to reduce the number of prefixes which could be used, 'preferred' prefixes have the form $10^{\pm 3n}$, where n is an integer. It may be noted that 'litre' (being 10^{-3} m³) and cP (being 10^{-3} kg/s m) happen to be preferred sub-multiples of the SI unit. 'Non-preferred' prefixes are not, however, vetoed if the context is appropriate.

Deviations from the SI

It has been internationally agreed that certain units which deviate from the coherence of the SI shall be retained, e.g.

(i) the usual larger units of time—minute (min = 60 s), hour (h = 3600 s), etc.
(ii) 360 degrees (2π rad) in a circle because of international practice
(iii) the kilo-watt-hour (kWh = 3·6 MJ), which is a deviation from the SI because the hour is not a decimal multiple of the second
(iv) customary Celsius scale-temperature °C, where t/°C = T/K − 273·15.

These are seen to be exceptions to the recommendation that only six base units (or their decimal multiples and fractions) should normally be used.

Symbols for *physical quantities* are printed in *italic* (sloping) type, and symbols for *units*, in roman (upright) type. In handwriting and typescript the distinction can be made (when necessary) by underlining the symbols for physical quantities.

Abbreviations for plurals do not take an 's'—e.g. the abbreviation for kilogrammes is kg, not kgs.

In division of one unit by others, only one solidus is used, e.g. acceleration is m/s^2, not m/s/s; and for dynamic viscosity 1 centipoise (1 cP) is 10^{-3} kg/sm and 1 centi-stoke (1 cSt) is 10^{-6} m^2/s.

Numbers are printed in upright type, and the decimal sign between digits is a point (·) placed above the line. To facilitate the reading of long numbers the digits are grouped in threes, but no comma is used, and the sign for multiplication of numbers is usually a cross (×).

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