A Guide to Fluid Mechanics

This book is written for the learner's point of view, with the purpose of helping readers understand the principles of flow. The theory is explained using ordinary and accessible language, where fluid mechanics is presented in analogy to solid mechanics to emphasize that they are all the application of Newtonian mechanics and thermodynamics. All the informative and helpful illustrations are drawn by the author, uniting the science and the art with figures that complement the text and provide clear understanding. Another unique feature is that one of the chapters is wholly dedicated to providing 25 selected interesting and controversial flow examples, with the purpose of linking theory with practice. The book will be useful to both beginners in the field and experts in other fields, and is ideal for college students, graduate students, engineers, and technicians.

Hongwei Wang graduated from Beihang University with a PhD major in turbomachinery and has been teaching fluid mechanics for 20 years. His key publication is the Chinese edition textbook *Fluid Mechanics as I Understand It*, published in December 2014, followed by the second edition published in March 2019. This book is no.1 best seller in fluid mechanics at China's biggest online retailer.

A Guide to Fluid Mechanics

HONGWEI WANG
Beihang University, Beijing

Translated by

YAN ZHANG
School of Computer and Software Engineering, Nanyang Institute of Technology

CAMBRIDGE
UNIVERSITY PRESS

CAMBRIDGE
UNIVERSITY PRESS

Shaftesbury Road, Cambridge CB2 8EA, United Kingdom

One Liberty Plaza, 20th Floor, New York, NY 10006, USA

477 Williamstown Road, Port Melbourne, VIC 3207, Australia

314–321, 3rd Floor, Plot 3, Splendor Forum, Jasola District Centre, New Delhi – 110025, India

103 Penang Road, #05–06/07, Visioncrest Commercial, Singapore 238467

Cambridge University Press is part of Cambridge University Press & Assessment, a department of the University of Cambridge.

We share the University's mission to contribute to society through the pursuit of education, learning and research at the highest international levels of excellence.

www.cambridge.org
Information on this title: www.cambridge.org/9781108498838

DOI: 10.1017/9781108671149

Original Title: 我所理解的流体力学（第2版）

English edition translated by Yan Zhang

First published 2023

A catalogue record for this publication is available from the British Library.

A Cataloging-in-Publication data record for this book is available from the Library of Congress.

ISBN 978-1-108-49883-8 Hardback
ISBN 978-1-108-71278-1 Paperback

Contents

Foreword

This book is written from the perspective of learners. Its aim is to elucidate the physical principles of flow, rather than be oriented toward engineering calculations. There are no example solutions or exercises in this book, so readers can understand the principles of fluid mechanics and enjoy the beauty of fluid motion with a relatively easy and interesting reading experience.

Socrates said: "Education is the kindling of a flame." Learning is a very personal thing. Only learners themselves can determine the success of learning. It is quite common for teachers to be enthused and excited on the podium while their students sleep soundly below. Regardless of how extensive the content of a textbook may be, how in-depth its discussions, and how rigorous its logic, if no one is willing to read it, its value will not be appreciated.

Science books should not be strictly divided into textbooks and popular science books. It is very important to get readers interested and to understand the so-called profound theories in an accessible way. Textbooks addressed to students should analyze problems from the learner's perspective, so that more students can enjoy the beauty of science through them, rather than developing a love of science by reading popular accounts of it. Rigor and popularity need not exclude each other. Through our efforts, we strive not only to maintain the scientific level of the discussion, but also to make it easier for readers to understand.

It should be the responsibility and obligation of teachers to deeply understand the subject and then to present it in an even more understandable way. This is a creative process that may be called the "reprocessing" of knowledge. In fact, the knowledge we have acquired is more or less written after "reprocessing." As authors of science books, teachers should strive to conduct a deep "reprocessing" of knowledge. There is no need to write another book if it only repeats what has already been said in previous books. While original discoveries and inventions are certainly important, the "reprocessing" and dissemination of knowledge are the keys to wider application. Euclid's *Elements of Geometry* and Newton's *Mathematical Principles of Natural Philosophy* are classic theoretical books. Nowadays, however, the teaching materials for college students are not these abstruse works, but more understandable versions written by Euclid's and Newton's successors who have mastered that ancient erudition.

A good textbook is not simply a restatement of facts, but a creative process rich in contributions. When I was a student, in addition to learning in class, I also studied, as a hobby, the teachers' lecturing styles. By comparing the way my teachers and I understood a topic, I figured out why students understood when teachers lectured in a certain way, and why it wasn't easy for them to grasp a concept when it was taught in a different way. I finally became a teacher myself. I naturally love teaching and I am appreciated by my students. At the beginning my focus was on preparing lectures and teaching methods. Later, I paid attention to knowledge understanding and student responses, thus achieving a reverse transformation from educator to learner. Now I regard every class as a new learning opportunity. During classroom sessions new questions constantly pop into my head, and I can often deepen my knowledge and gain new insights, which is what every student should do in class. As I have my own unique understanding of what is taught, I believed that it should be written down for more people to see it and benefit from it. That's why I wrote this book.

However, there are risks in publishing my own understanding of fluid mechanics. One's interpretations could be faulty, or not rigorous enough. Will these shortcomings mislead students? I think this is why, although many teachers can make their teaching lively in class, the textbooks they write are obscure or difficult to understand. If we faithfully follow classical works and take rigor as the highest priority, it is not necessary to write another introductory book on some well-established area such as fluid mechanics. Therefore, I decided to take the risk and write a book based on my personal understanding of the subject, which I believe will be helpful to junior readers of fluid mechanics.

Now, let me introduce the contents and characteristics of this book. It is not a popular science book, but can be used as a textbook. For this, it only needs to be supplemented with examples and exercises. There are numerous formulas and derivations in the book, even more than in many undergraduate textbooks. It is said that each additional formula will scare one reader away. I admit that this claim may be right. However, scaring your readers away does not necessarily need formulas. There are actually very few formulas in Newton's *Mathematical Principles of Natural Philosophy*, but it is not any easier to read than modern textbooks that contain plenty of formulas. After all, mathematics is the language of science, and I have no intention of weakening its role. On the contrary, I even hope that readers will have a deeper understanding of some mathematical concepts through the application of them to mechanics.

Compared with existing teaching materials and books on the same topic, this one has some distinctive characteristics, among which the many exquisite color pictures are the most intuitive. All of these pictures have been hand-drawn by myself. Of course, some drawings refer to relevant books, but I tried to strike a balance between scientific accuracy and aesthetics. I can guarantee that all curve graphics can be directly used as a reference for engineering applications, and all flow images are in line with the actual conditions.

In the final chapter I included 25 interesting and useful flow examples for in-depth analysis, so that readers can enjoy the experience of learning and applying their knowledge. For example: What is the shape of falling raindrops? Why will outlet velocity increase if you squeeze the outlet of a watering hose? As long as their thinking is inquisitive, anyone who has learned the basics of fluid mechanics should be able to explain these everyday phenomena.

This book is suitable as a supplementary textbook for students, as well as for self-study material for engineering and technical personnel. Readers who are studying fluid mechanics for the first time, and using this book as a textbook or as self-study material, will find that a large number of concepts in classical physics, theoretical mechanics, and solid mechanics are used. Therefore, they do not need to regard fluid mechanics as a completely separate discipline, which will make their learning easier. By placing understanding at its core, this book is also highly suitable as a textbook for those who have studied fluid mechanics before and seek to refresh their knowledge of it.

I hope that this translated version of the book brings a new experience to English-language readers, and I would be very happy if it could also provide them with a deeper understanding of some facts or concepts.

I am indebted to my alumni Dr. Yan Zhang, who translated the entire book from Chinese into English, for his elaborate work. Also, the extensive efforts and excellent work of Prof. Arturo Sangalli are truly appreciated, for the intensive grammar checking and creative text polishing.

Nomenclature

Notation

$\vec{f}$	Vector quantities
$\overline{f}$	Average of f
f'	(1) Derivative of f
	(2) Perturbation of f
f^*	Dimensionless value of f
f_{cr}	Critical value of f
f_∞	Value of f far away from the point of interest
Δf	Change of f
δf	Infinitesimal change of f
$\mathrm{d}f$	(1) Differential of f
	(2) Infinitesimal change of f
$\mathrm{D}f/\mathrm{D}t$	Material derivative of f

Letters

a	(1) Speed of sound
	(2) Acceleration
A	Area or surface
AR	Diffuser or nozzle area ratio (exit area/inlet area)
B	Volume
const	A constant
c_{p}	Specific heat at constant pressure
c_{v}	Specific heat at constant volume
C_{f}	Skin friction parameter
C_{p}	Pressure rise coefficient
C_{D}	Drag coefficient
d	Diameter
D	(1) Diameter
	(2) Drag force
e	Total energy per unit mass

E	Total energy
Eu	Euler number
f	(1) Force per unit mass
	(2) Friction factor
f_b	Body force per unit mass
F	Force
Fr	Froude number
g	Gravitational acceleration
G	Gravitational force
h	(1) Enthalpy per unit mass
	(2) Height
h_t	Stagnation enthalpy per unit mass
H	Boundary layer shape factor
i	Imaginary root
k	(1) Thermal conductivity
	(2) Specific heat ratio
L	Length
m	Mass
$\dot{m}$	Mass flow rate
M	Molar mass
Ma	Mach number
n	Normal unit vector
p	Pressure
p_0	Atmospheric pressure
p_t	Stagnation pressure
$\dot{q}$	Rate of heat per unit mass
$\dot{q}_x$	Rate of heat per unit mass per unit area
$q(\lambda)$, $q(Ma)$	Mass flow function
$\dot{Q}$	Rate of heat
r, R	Radius
$\vec{r}$	Position vector
R	Gas constant of air
R_0	Universal gas constant
Re	Reynolds number
s	(1) Entropy per unit mass
	(2) Streamwise unit vector
S	Entropy
St	Strouhal number
t	Time
T	Temperature
T_t	Stagnation temperature
u, v, w	Velocity components in Cartesian coordinates
u_i	Velocity components in Tensor form

$\hat{u}$	Internal energy
U	Reference velocity or characteristic velocity
v	(1) Velocity component in y direction
	(2) Specific volume (volume per unit mass)
V	Velocity magnitude
w	(1) Velocity component in z direction
	(2) Work per unit mass
w_s	Shaft work per unit mass
W	Work
We	Weber number
x, y, z	Cartesian coordinates

Symbols

α	Planar diffuser half-angle
β	Shock angle
Γ	(1) Stress
	(2) Circulation
δ	(1) Deflection angle
	(2) Boundary layer thickness
δ_{ij}	Kronecker delta
δ^*	Boundary layer displacement thickness
Δ	Difference of change
ε	Strain rate
η	Dimensionless distance from wall
θ	(1) Boundary layer momentum thickness
	(2) Circumferential coordinate
λ	(1) Coefficient of thermal conductivity
	(2) Coefficient of velocity
μ	Dynamic viscosity
ν	Kinematic viscosity
ρ	Density
Ψ	Stream function
τ	Shear stress
ϕ	(1) Velocity potential
	(2) Some mechanical property per unit mass
Φ	Some mechanical property
Φ_v	Dissipation function
ω	Vorticity
Ω	Angular velocity

Subscripts

b	Body (as in body force)
c	Center or core
cr	Critical condition
cv	Control volume
D	(1) Diameter (as in Reynolds number)
	(2) Drag (as in drag force)
e	Exit station
i	Inlet station
i, j, k	Indices of Tensor
n	Normal direction or component
r	Radial direction or component
s	Streamwise direction
sys	System
t	Stagnation condition
x, y, z	Components in x, y, z directions

Cambridge University Press & Assessment
978-1-108-49883-8 — A Guide to Fluid Mechanics
Hongwei Wang
Frontmatter
More Information