
Fluid Mechanics
3rd Edition
流体力学
第3版
J.F. Douglas
J.M. Gasiorek
J.A. Swaffield

Fluid Mechanics

J. F. DOUGLAS
M.Sc. (Eng.), Ph.D., A.C.G.I., D.I.C., C.Eng., M.I.C.E., M.I.Mech.E.
Formerly of Mechanical Engineering Department, University of the South Bank, London

J. M. GASIOREK
B.Sc. (Eng.), Ph.D., C.Eng., M.I.Mech.E., M.C.I.B.S
Formerly of Mechanical Engineering Department, University of the South Bank, London

and

J. A. SWAFFIELD
B.Sc., M.Phil., Ph.D., C.Eng., M.R.Ae.S., F.I.W.E.M., M.C.I.B.S.E.
William Watson Professor of Building Engineering
Heriot-Watt University, Edinburgh

Third edition

世界图书出版公司

书　　名：Fluid Mechanics　3rd ed.
作　　者：J.F.Douglas, J.M.Gasiorek, et al.
中 译 名：流体力学　第 3 版
出 版 者：世界图书出版公司北京公司
印 刷 者：北京中西印刷厂
发　　行：世界图书出版公司北京公司 (北京朝内大街 137 号　100010)
开　　本：1/24　711×1245　印　张：35.5
出版年代：2000 年 6 月
书　　号：ISBN 7-5062-4706-2/ O・289
版权登记：图字 01-1999-2128
定　　价：145.00 元

Addison Wesley Longman Limited
Edinburgh Gate,
Harlow, Essex CM20 2JE.
United Kingdom
and Associated Companies throughout the world.

Reprinted 1995, Reprinted 1996, Reprinted 1998

First edition published by Pitman Publishing Limited 1979
Second edition 1985
Third edition published by Longman Scientific & Technical 1995

British Library Cataloguing in Publication Data
A catalogue entry for this title is available from the British Library.

ISBN 0-582-23408-5

Library of Congress Cataloging-in-Publication Data
Douglas, John F.
Fluid mechanics / J. F. Douglas, J.M. Gasiorek, and J. A. Swaffield. —3rd ed.
p. cm.
Included bibliographical references and index.
1. Fluid mechanics. I. Swaffield, J. A., 1943—
II. Gasiorek, J. M. (Janusz Maria), 1927— . III. Title.
TA357.D68 1995
620.1' 06—dc20 94-18461 CIP

This edition of Fluid Mechanics,Third Edition is published by arrangement with Pearson Education Limited.

Preface to the Third Edition

This third edition of *Fluid Mechanics* has retained the aims of the original text in providing a broad-based approach to the study of fluid flow together with a detailed and more advanced treatment of specialist topics that find wide application within the design and analysis of flow systems. The text repeats the previous mix of exposition and example shown to be successful by earlier editions.

The study of fluid flow is one of the few areas within engineering that truly crosses the boundaries between the various engineering disciplines. It is of equal importance to mechanical, civil, chemical and process, aeronautical and environmental and building services engineers and is to be found as a fundamental building block in the education and formation of these engineers. While this has remained true, the techniques available to enable students to achieve an understanding of fluid mechanics have been revolutionized by the readily available access to computing facilities; facilities that have already advanced immeasurably since the second edition of this text was published. The use of the computer to aid understanding through the provision of interactive simulations, including the use of multi-media packages, will undoubtedly advance even more rapidly during the lifetime of this edition. Whereas the second edition was accompanied by an optional floppy disk containing the programs presented in the text, this is no longer appropriate. Instead the program listings, including a number of new or enhanced programs, have been presented in a format that will make them readily scannable and so usable on a wide range of machines.

While the third edition text retains the philosophy and methodology introduced with the earlier editions, the content has been refined to both extend and, in the authors' view, improve the presentation of existing material. In particular the text has been reordered to present earlier the fundamentals of dimensional analysis and the laws of similarity. The treatment given to the steady flow energy equation has been extended, together with a general enhancement of the analysis of air and gas flow networks. In this context the coverage of fans within rotodynamic machinery has been strengthened and new material covering the use of fans in ventilation, and the ventilation of tunnels by jet fans in particular, has been presented. A new chapter dealing with the mechanisms of mechanical and natural ventilation has been added to provide both a treatment of this important topic and a background to one of the most common applications for fan technology.

As in previous editions current research has been utilized in the treatment of specialist topics, such as the jet fan tunnel ventilation and the unsteady flow analysis presentations. In the latter case the treatment presented in this edition

seeks to emphasize the commonality of a range of unsteady flow analyses, from classical waterhammer to free surface waves and low-amplitude transient propagation in gas flows, by demonstrating the general development of the defining equations and the identical solution by finite difference techniques, allied to computer simulation, once the appropriate terms have been identified for each application.

Once again the authors would like to thank all their colleagues in the many universities in the UK and overseas who have contributed to this text by their support for, and comments on, the earlier editions. The authors are grateful to the staff at Longman, particularly Ian Francis and Chris Leeding, who have both supported us in completing this edition and shown considerable patience with the process. Nevertheless, any errors, factual or of understanding, remain ours. We have found fluid mechanics, in all its multi-disciplinary manifestations, to be the most stimulating of engineering areas; we hope that this text will communicate some of that experience and enthusiasm to students of this most demanding of engineering disciplines.

J. F. Douglas
J. M. Gasiorek
J. A. Swaffield

Edinburgh, December 1993

Preface to the Second Edition

In the preparation of this second edition we have retained the aims of the original text, namely to provide a broad-based treatment of the essentials of Fluid Mechanics, while at the same time demonstrating the application of the subject, particularly to the study and solution of higher level problems in selected areas. In retaining this 'applications' approach we are both aware and pleased that this technique currently features in the UK Engineering Council statements on the training, education and 'formation' of engineers, strengthening our view that this is one of the most efficient and relevant methods of helping students in general to understand our subject. We believe that such an approach should also include the use of improved computer-based numerical solutions as these will become part of the engineer's everyday activities.

In the five years since the first edition was published there has been a significant change in the availability of and access to micro and other computers for both the student and the practising engineer. Computers and programs are of course not ends in themselves but rather they are powerful tools that we can utilize to dispense with many tedious and repetitive calculations, thereby allowing the study, within an educational framework, of problems of greater complexity and relevance, including time-dependent phenomena that were previously beyond our capability without recourse to simplifying assumptions. This second edition therefore includes a series of computer programs chosen to illustrate these aspects of computer application and to be of direct use to both student and practising engineer alike. While the programs have been written in BBC Basic they may be transferred with little difficulty to Apple, Commodore or Sinclair machines. A program cassette tape will also be available to support the text.

None of this of course removes the necessity to provide a thorough basis for the subject and this remains one of the text's main objectives. We have included new material in areas that have been found particularly interesting by our readers, as well as updating and refining the existing text. The treatment of incompressible flows around a body has been extended to include the study of wakes, while the coverage of fluid machinery has been strengthened by the inclusion of a major new chapter on positive displacement machines. The existing treatment of unsteady flow has been extended to allow the application of numerical modelling techniques to unsteady open channel or partially filled pipe flows. Taken together with the introduction of computing methods we

view these additions as supporting and reaffirming the aims and objectives of the original text.

Once again we would like to thank all our colleagues in many universities and polytechnics in the UK and overseas who have encouraged us by their positive response to and constructive comments on the first edition. All have helped us to formulate this new edition which we hope will fulfil a useful role for both the student and the practising engineer.

J. F. Douglas
J. M. Gasiorek
J. A. Swaffield

London, May 1984

Preface to the First Edition

This is a textbook for all manner of engineers. Whether the reader is concerned with Civil, Mechanical or Chemical Engineering, Buiding Services or Environmental Engineering, the principles of fluid mechanics remain the same. Drawing on our joint experience of teaching students in all these disciplines, we have tried to set out these principles simply and clearly and to illustrate their application by examples drawn from the various branches of engineering.

In the planning of this book we are indebted to our colleagues in other Colleges, Polytechnics and Universities for the opportunity to study their syllabuses and examination papers which has enabled us to cover the general requirements of the Honours Degree and Professional examinations. We have also deliberately dealt with the elementary aspects of the subject very fully and so the book will meet the requirements of those studying for the Higher National Diploma or for the Higher Diploma or Higher Certificate of the Business and Technician Education Council (B.T.E.C.).

For ease of reference the contents has been divided into Parts which are substantially self-contained and we hope that they will provide a convenient source of information for the practising engineer in his day to day activities.

J. F. Douglas
J. M. Gasiorek
J. A. Swaffield

List of Symbols

a	acceleration, area
A	area, constant
b	width, breadth
B	width, breadth, constant
c	chord length, velocity of sound
c_p	specific heat at constant pressure
c_v	specific heat at constant volume
C	constant
C_c	coefficient of contraction
C_d	coefficient of discharge
C_D	coefficient of drag
C_f	coefficient of friction
C_L	coefficient of lift
C_v	coefficient of velocity
d	diameter
D	drag, diameter, depth
e	base of natural logarithms
e	error, internal energy per unit mass
E	modulus of elasticity, energy
f	friction factor
$f( )$	reflected pressure wave
F	force, stress
$F( )$	pressure wave
g	gravitational acceleration
h	vertical height, depth
h	head loss
H	head, enthalpy
i	hydraulic gradient
I	moment of inertia
k	constant, radius of gyration
K	bulk modulus
l	length
L	lift
m	mass, area ratio, doublet strength, hydraulic mean depth
M	molecular weight
n	number of, polytropic index

N	rotational speed
p	pressure
P	force, power, wetted perimeter
q	flow rate per unit width or unit depth
Q	volumetric flow rate
r	radius, radial distance
R	radius, reaction force
$\boldsymbol{R}$	gas constant
s	slope, distance, arbitrary coordinate within Cartesian system, slip
S	surface, entropy
t	time
T	temperature, torque surface width
u	velocity, peripheral blade velocity
U	internal energy, velocity
v, V	velocity
v_f	velocity of flow
v_r	relative velocity
v_x	velocity component in x direction
v_y	velocity component in y direction
v_z	velocity component in z direction
v_r	radial velocity
v_θ	tangential velocity
V	volume
w	specific weight
W	weight, work
x, y, z	orthogonal coordinates
y	gas content (per cent)
Z	potential head, depth

α	angle, angular acceleration
β	angle
γ	adiabatic index (c_p/c_v)
Γ	circulation
δ	difference, increment
Δ	change in
ε	absolute roughness, eddy viscosity
ζ	vorticity
η	efficiency
θ	angle
μ	coefficient of dynamic viscosity
ν	coefficient of kinematic viscosity, Poisson's ratio
ρ	mass density
σ	relative density (specific gravity), surface tension
τ	shear stress
ϕ	shear strain, angle
Φ	velocity potential
Ψ	stream function
ω	angular (rotational) velocity, stage variable

Fr	Froude number
Ma	Mach number
Re	Reynolds number
Str	Strouhal number
We	Weber number
L	Dimensions of length
M	Dimensions of mass
T	Dimensions of time
Θ	Dimensions of temperature

List of Computer Programs

Contents

Part II Concepts of Fluid Flow