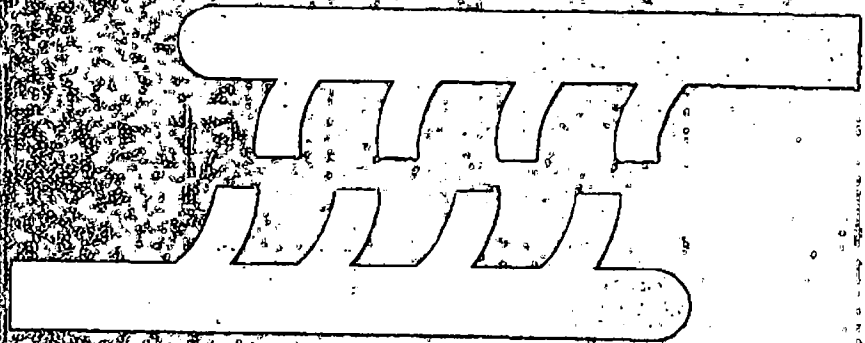


Internal Combustion Engine Fundamentals



John B. Heywood

INTERNAL COMBUSTION ENGINE FUNDAMENTALS

John B. Heywood

*Professor of Mechanical Engineering
Director, Sloan Automotive Laboratory
Massachusetts Institute of Technology*

McGraw-Hill, Inc.

New York St. Louis San Francisco Auckland Bogotá
Caracas Lisbon London Madrid Mexico City Milan
Montreal New Delhi San Juan Singapore
Sydney Tokyo Toronto

INTERNAL COMBUSTION ENGINE FUNDAMENTALS

This book was set in Times Roman.
The editors were Anne Duffy and John M. Morriss; the designer was Joan E. O'Connor; the production supervisor was Denise L. Puryear. New drawings were done by ANCO. Project Supervision was done by Santype International Ltd. R. R. Donnelley & Sons Company was printer and binder.

See acknowledgements on page xxi.

Copyright © 1988 by McGraw-Hill, Inc. All rights reserved.
Printed in the United States of America. Except as permitted under the United States Copyright Act of 1976, no part of this publication may be reproduced or distributed in any form or by any means, or stored in a data base or retrieval system, without the prior written permission of the publisher.

12 13 14 15 16 17 DOC/DOC 9 9 8 7 6

ISBN 0-07-028637-X

Library of Congress Cataloging-in-Publication Data

Heywood, John B.

Internal combustion engine fundamentals.

(McGraw-Hill series in mechanical engineering)

Bibliography: p.

Includes index.

1. Internal combustion engines. I. Title. II. Series.
TJ755.H45 1988 621.43 87-15251

This book is printed on acid-free paper.

McGraw-Hill Series in Mechanical Engineering

Jack P. Holman, *Southern Methodist University*
Consulting Editor

Anderson: *Modern Compressible Flow: With Historical Perspective*
Dieter: *Engineering Design: A Materials and Processing Approach*
Eckert and Drake: *Analysis of Heat and Mass Transfer*
Heywood: *Internal Combustion Engine Fundamentals*
Hinze: *Turbulence, 2/e*
Hutton: *Applied Mechanical Vibrations*
Juvinall: *Engineering Considerations of Stress, Strain, and Strength*
Kane and Levinson: *Dynamics: Theory and Applications*
Kays and Crawford: *Convective Heat and Mass Transfer*
Martin: *Kinematics and Dynamics of Machines*
Phelan: *Dynamics of Machinery*
Phelan: *Fundamentals of Mechanical Design, 3/e*
Pierce: *Acoustics: An Introduction to Its Physical Principles and Applications*
Raven: *Automatic Control Engineering, 4/e*
Rosenberg and Karnopp: *Introduction to Physics*
Schlichting: *Boundary-Layer Theory, 7/e*
Shames: *Mechanics of Fluids, 2/e*
Shigley: *Kinematic Analysis of Mechanisms, 2/e*
Shigley and Mitchell: *Mechanical Engineering Design, 4/e*
Shigley and Uicker: *Theory of Machines and Mechanisms*
Stoecker and Jones: *Refrigeration and Air Conditioning, 2/e*
Vanderplaats: *Numerical Optimization Techniques for Engineering Design:
With Applications*