Marks'
Standard Handbook for Mechanical Engineers

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Marks'
Standard Handbook for Mechanical Engineers

Revised by a staff of specialists

EUGENE A. AVALLONE ***Editor***

Consulting Engineer; Professor of Mechanical Engineering, Emeritus
The City College of the City University of New York

THEODORE BAUMEISTER III ***Editor***

Retired Consultant, Information Systems Department
E. I. du Pont de Nemours & Co.

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Contributors

Abraham Abramowitz *Consulting Engineer; Professor of Electrical Engineering, Emeritus, The City College, The City University of New York* (ILLUMINATION)

Vincent M. Altamuro *President, VMA, Inc., Toms River, NJ* (MATERIAL HOLDING AND FEEDING. CONVEYOR MOVING AND HANDLING. AUTOMATED GUIDED VEHICLES AND ROBOTS. MATERIAL STORAGE AND WAREHOUSING. METHODS ENGINEERING. AUTOMATED MANUFACTURING. INDUSTRIAL PLANTS)

Alger Anderson *Vice President, Engineering, Research & Product Development, Lift-Tech International, Inc.* (OVERHEAD TRAVELING CRANES)

William Antis* *Technical Director, Maynard Research Council, Inc., Pittsburgh, PA* (METHODS ENGINEERING)

Dennis N. Assanis *Professor of Mechanical Engineering, University of Michigan* (INTERNAL COMBUSTION ENGINES)

Klemens C. Baczewski *Consulting Engineer* (CARBONIZATION OF COAL AND GAS MAKING)

Glenn W. Baggley *Manager, Regenerative Systems, Bloom Engineering Co., Inc.* (COMBUSTION FURNACES)

Frederick G. Bailey *Consulting Engineer; formerly Technical Coordinator, Thermodynamics and Applications Engineering, General Electric Co.* (STEAM TURBINES)

Antonio F. Baldo *Professor of Mechanical Engineering, Emeritus, The City College, The City University of New York* (NONMETALLIC MATERIALS. MACHINE ELEMENTS)

Robert D. Bartholomew *Sheppard T. Powell Associates, LLC* (CORROSION)

George F. Baumeister *President, EMC Process Corp., Newport, DE* (MATHEMATICAL TABLES)

Heard K. Baumeister *Senior Engineer, Retired, International Business Machines Corp.* (MECHANISM)

Howard S. Bean* *Late Physicist, National Bureau of Standards* (GENERAL PROPERTIES OF MATERIALS)

E. R. Behnke* *Product Manager, CM Chain Division, Columbus, McKinnon Corp.* (CHAINS)

John T. Benedict *Retired Standards Engineer and Consultant, Society of Automotive Engineers* (AUTOMOTIVE ENGINEERING)

C. H. Berry* *Late Gordon McKay Professor of Mechanical Engineering, Harvard University; Late Professor of Mechanical Engineering, Northeastern University* (PREFERRED NUMBERS)

Louis Bialy *Director, Codes & Product Safety, Otis Elevator Company* (ELEVATORS, DUMBWAITERS, AND ESCALATORS)

Malcolm Blair *Technical and Research Director, Steel Founders Society of America* (IRON AND STEEL CASTINGS)

Omer W. Blodgett *Senior Design Consultant, Lincoln Electric Co.* (WELDING AND CUTTING)

Donald E. Bolt *Engineering Manager, Heat Transfer Products Dept., Foster Wheeler Energy Corp.* (POWER PLANT HEAT EXCHANGERS)

Claus Borgnakke *Associate Professor of Mechanical Engineering, University of Michigan* (INTERNAL COMBUSTION ENGINES)

G. David Bounds *Senior Engineer, PanEnergy Corp.* (PIPELINE TRANSMISSION)

William J. Bow *Director, Retired, Heat Transfer Products Department, Foster Wheeler Energy Corp.* (POWER PLANT HEAT EXCHANGERS)

James L. Bowman *Senior Engineering Consultant, Rotary-Reciprocating Compressor Division, Ingersoll-Rand Co.* (COMPRESSORS)

Aine Brazil *Vice President, Thornton-Tomasetti/Engineers* (STRUCTURAL DESIGN OF BUILDINGS)

Frederic W. Buse* *Chief Engineer, Standard Pump Division, Ingersoll-Rand Co.* (DISPLACEMENT PUMPS)

*Contributions by authors whose names are marked with an asterisk were made for the previous edition and have been revised or rewritten by others for this edition. The stated professional position in these cases is that held by the author at the time of his or her contribution.

C. P. Butterfield *Chief Engineer, Wind Technology Division, National Renewable Energy Laboratory* (WIND POWER)

Benson Carlin* *President, O.E.M. Medical, Inc.* (SOUND, NOISE, AND ULTRASONICS)

C. L. Carlson* *Late Fellow Engineer, Research Labs., Westinghouse Electric Corp.* (NONFERROUS METALS)

Vittorio (Rino) Castelli *Senior Research Fellow, Xerox Corp.* (FRICTION, FLUID FILM BEARINGS)

Michael J. Clark *Manager, Optical Tool Engineering and Manufacturing, Bausch & Lomb, Rochester, NY* (OPTICS)

Ashley C. Cockerill *Staff Engineer, Motorola Corp.* (ENGINEERING STATISTICS AND QUALITY CONTROL)

Aaron Cohen *Retired Center Director, Lyndon B. Johnson Space Center, NASA and Zachry Professor, Texas A&M University* (ASTRONAUTICS)

Arthur Cohen *Manager, Standards and Safety Engineering, Copper Development Assn.* (COPPER AND COPPER ALLOYS)

D. E. Cole *Director, Office for Study of Automotive Transportation, Transportation Research Institute, University of Michigan* (INTERNAL COMBUSTION ENGINES)

James M. Connolly *Section Head, Projects Department, Jacksonville Electric Authority* (COST OF ELECTRIC POWER)

Robert T. Corry* *Retired Associate Professor of Mechanical and Aerospace Engineering, Polytechnic University* (INSTRUMENTS)

Paul E. Crawford *Partner; Connolly, Bove, Lodge & Hutz; Wilmington, DE* (PATENTS, TRADEMARKS, AND COPYRIGHTS)

M. R. M. Crespo da Silva* *University of Cincinnati* (ATTITUDE DYNAMICS, STABILIZATION, AND CONTROL OF SPACECRAFT)

Julian H. Dancy *Consulting Engineer, Formerly Senior Technologist, Technology Division, Fuels and Lubricants Technology Department, Texaco, Inc.* (LUBRICANTS AND LUBRICATION)

Benjamin B. Dayton *Consulting Physicist, East Flat Rock, NC* (HIGH-VACUUM PUMPS)

Rodney C. DeGroot *Research Plant Pathologist, Forest Products Lab., USDA* (WOOD)

Joseph C. Delibert *Retired Executive, The Babcock and Wilcox Co.* (STEAM BOILERS)

Donald D. Dodge *Supervisor, Retired, Product Quality and Inspection Technology, Manufacturing Development, Ford Motor Co.* (NONDESTRUCTIVE TESTING)

Joseph S. Dorson *Senior Engineer, Columbus McKinnon Corp.* (CHAIN)

Michael B. Duke *Chief, Solar Systems Exploration, Johnson Space Center, NASA* (ASTRONOMICAL CONSTANTS OF THE SOLAR SYSTEM, DYNAMIC ENVIRONMENTS. SPACE ENVIRONMENT)

F. J. Edeskuty *Retired Associate, Los Alamos National Laboratory* (CRYOGENICS)

O. Elnan* *University of Cincinnati* (SPACE-VEHICLE TRAJECTORIES, FLIGHT MECHANICS, AND PERFORMANCE. ORBITAL MECHANICS)

Robert E. Eppich *Vice President, Technology, American Foundrymen's Society* (IRON AND STEEL CASTINGS)

C. James Erickson* *Principal Consultant, Engineering Department. E. I. du Pont de Nemours & Co.* (ELECTRICAL ENGINEERING)

George H. Ewing* *Retired President and Chief Executive Officer, Texas Eastern Gas Pipeline Co. and Transwestern Pipeline Co.* (PIPELINE TRANSMISSION)

Erich A. Farber *Distinguished Service Professor Emeritus; Director, Emeritus, Solar Energy and Energy Conversion Lab., University of Florida* (HOT AIR ENGINES. SOLAR ENERGY. DIRECT ENERGY CONVERSION)

D. W. Fellenz* *University of Cincinnati* (SPACE-VEHICLE TRAJECTORIES, FLIGHT MECHANICS, AND PERFORMANCE. ATMOSPHERIC ENTRY)

Arthur J. Fiehn* *Late Retired Vice President, Project Operations Division, Burns & Roe, Inc.* (COST OF ELECTRIC POWER)

Sanford Fleeter *Professor of Mechanical Engineering and Director, Thermal Sciences and Propulsion Center, School of Mechanical Engineering, Purdue University* (JET PROPULSION AND AIRCRAFT PROPELLERS)

William L. Gamble *Professor of Civil Engineering, University of Illinois at Urbana-Champaign* (CEMENT, MORTAR, AND CONCRETE. REINFORCED CONCRETE DESIGN AND CONSTRUCTION)

Daniel G. Garner* *Senior Program Manager, Institute of Nuclear Power Operations, Atlanta, GA* (NUCLEAR POWER)
Burt Garofab *Senior Engineer, Pittston Corp.* (MINES, HOISTS, AND SKIPS. LOCOMOTIVE HAULAGE, COAL MINES)
Siamak Ghofranian *Senior Engineer, Rockwell Aerospace* (DOCKING OF TWO FREE-FLYING SPACECRAFT)
Samuel V. Glorioso *Section Chief, Metallic Materials, Johnson Space Center, NASA* (STRESS CORROSION CRACKING)
Norman Goldberg *Consulting Engineer* (HEATING, VENTILATION, AND AIR CONDITIONING)
David T. Goldman *Deputy Manager, U.S. Department of Energy, Chicago Operations Office* (MEASURING UNITS)
Frank E. Goodwin *Vice President, Materials Science, ILZRO, Inc.* (BEARING METALS. LOW-MELTING-POINT METALS AND ALLOYS. ZINC AND ZINC ALLOYS)
Don Graham *Manager, Turning Programs, Carboloy, Inc.* (CEMENTED CARBIDES)
John E. Gray* *ERCI, Intl.* (NUCLEAR POWER)
David W. Green *Supervisory Research General Engineer, Forest Products Lab., USDA* (WOOD)
Walter W. Guy *Chief, Crew and Thermal Systems Division, Johnson Space Center, NASA* (SPACECRAFT LIFE SUPPORT AND THERMAL MANAGEMENT)
Harold V. Hawkins* *Late Manager, Product Standards and Services, Columbus McKinnon Corp.* (DRAGGING, PULLING, AND PUSHING. PIPELINE FLEXURE STRESSES)
Keith L. Hawthorne *Senior Assistant Vice President, Transportation Technology Center, Association of American Railroads* (RAILWAY ENGINEERING)
V. T. Hawthorne *Vice President, Engineering and Technical Services, American Steel Foundries* (RAILWAY ENGINEERING)
J. Edmund Hay *U.S. Department of the Interior* (EXPLOSIVES)
Roger S. Hecklinger *Project Director, Roy F. Weston of New York. Inc.* (INCINERATION)
Terry L. Henshaw *Consulting Engineer, Battle Creek, MI* (DISPLACEMENT PUMPS)
Roland Hernandez *Research General Engineer, Forest Products Lab., USDA* (WOOD)
Hoyt C. Hottel *Professor Emeritus, Massachusetts Institute of Technology* (RADIANT HEAT TRANSFER)
R. Eric Hutz *Associate; Connolly, Bove, Lodge, & Hutz; Wilmington, DE* (PATENTS, TRADEMARKS, AND COPYRIGHTS)
Michael W. M. Jenkins *Professor, Aerospace Design, Georgia Institute of Technology* (AERONAUTICS)
Peter K. Johnson *Director, Marketing and Public Relations, Metal Powder Industries Federation* (POWDERED METALS)
Randolph T. Johnson *Naval Surface Warfare Center* (ROCKET FUELS)
Robert L. Johnston *Branch Chief, Materials, Johnson Space Center, NASA* (METALLIC MATERIALS FOR AEROSPACE APPLICATIONS. MATERIALS FOR USE IN HIGH-PRESSURE OXYGEN SYSTEMS)
Byron M. Jones *Retired Associate Professor of Electrical Engineering, School of Engineering, University of Tennessee at Chattanooga* (ELECTRONICS)
Scott K. Jones *Associate Professor, Department of Accounting, University of Delaware* (COST ACCOUNTING)
Robert Jorgensen *Engineering Consultant* (FANS)
Serope Kalpakjian *Professor of Mechanical and Materials Engineering, Illinois Institute of Technology* (METAL REMOVAL PROCESSES AND MACHINE TOOLS)
Igor J. Karassik *Late Senior Consulting Engineer, Ingersoll-Dresser Pump Co.* (CENTRIFUGAL AND AXIAL FLOW PUMPS)
Robert W. Kennard* *Lake-Sumter Community College, Leesburg, FL* (ENGINEERING STATISTICS AND QUALITY CONTROL)
Edwin E. Kintner* *Executive Vice President, GPU Nuclear Corp., Parsippany, NJ* (NUCLEAR POWER)
J. Randolph Kissell *Partner, The TGB Partnership* (ALUMINUM AND ITS ALLOYS)
Andrew C. Klein *Associate Professor, Nuclear Engineering, Oregon State University* (ENVIRONMENTAL CONTROL. OCCUPATIONAL SAFETY AND HEALTH. FIRE PROTECTION)
Ezra S. Krendel *Emeritus Professor of Operations Research and Statistics, Wharton School, University of Pennsylvania* (HUMAN FACTORS AND ERGONOMICS. MUSCLE GENERATED POWER)
A. G. Kromis* *University of Cincinnati* (SPACE-VEHICLE TRAJECTORIES, FLIGHT MECHANICS, AND PERFORMANCE)
P. G. Kuchuris, Jr.* *Market Planning Manager, International Harvester Co.* (OFF-HIGHWAY VEHICLES AND EARTHMOVING EQUIPMENT)
L. D. Kunsman* *Late Fellow Engineer, Research Labs., Westinghouse Electric Corp.* (NONFERROUS METALS)
Colin K. Larsen *Vice President, Blue Giant U.S.A. Corp.* (SURFACE HANDLING)
Lubert J. Leger *Deputy Branch Chief, Materials, Johnson Space Center, NASA* (SPACE ENVIRONMENT)
John H. Lewis *Technical Staff, Pratt & Whitney, Division of United Technologies Corp.; Adjunct Associate Professor, Hartford Graduate Center, Renssealear Polytechnic Institute* (GAS TURBINES)
Peter E. Liley *Professor, School of Mechanical Engineering, Purdue University* (THERMODYNAMICS, THERMODYNAMIC PROPERTIES OF SUBSTANCES)
Michael K. Madsen *Manager, Industrial Products Engineering, Neenah Foundry Co.* (FOUNDRY PRACTICE AND EQUIPMENT)
C. J. Manney* *Consultant, Columbus McKinnon Corp.* (HOISTS)
Ernst K. H. Marburg *Manager, Product Standards and Service, Columbus McKinnon Corp.* (LIFTING, HOISTING, AND ELEVATING. DRAGGING, PULLING, AND PUSHING. LOADING, CARRYING, AND EXCAVATING)
Adolph Matz* *Late Professor Emeritus of Accounting, The Wharton School, University of Pennsylvania* (COST ACCOUNTING)
Leonard Meirovitch *University Distinguished Professor, Department of Engineering Science and Mechanics, Virginia Polytechnic Institute and State University* (VIBRATION)
Sherwood B. Menkes *Professor of Mechanical Engineering, Emeritus, The City College, The City University of New York* (FLYWHEEL ENERGY STORAGE)
George W. Michalec *Consulting Engineer, Formerly Professor and Dean of Engineering and Science, Stevens Institute of Technology* (GEARING)
Duane K. Miller *Welding Design Engineer, Lincoln Electric Co.* (WELDING AND CUTTING)
Russell C. Moody *Supervisory Research General Engineer, Forest Products Lab., USDA* (WOOD)
Ralph L. Moore* *Retired Systems Consultant, E. I. du Pont de Nemours & Co.* (AUTOMATIC CONTROLS)
Thomas L. Moser *Deputy Associate Administrator, Office of Space Flight, NASA Headquarters, NASA* (SPACE-VEHICLE STRUCTURES)
George J. Moshos *Professor Emeritus of Computer and Information Science, New Jersey Institute of Technology* (COMPUTERS)
Otto Muller-Girard *Consulting Engineer* (INSTRUMENTS)
James W. Murdock *Late Consulting Engineer* (MECHANICS OF FLUIDS)
Gregory V. Murphy *Process Control Consultant, DuPont Co.* (AUTOMATIC CONTROLS)
Joseph F. Murphy *Supervisory General Engineer, Forest Products Lab., USDA* (WOOD)
John Nagy *Retired Supervisory Physical Scientist, U.S. Department of Labor, Mine Safety and Health Administration* (DUST EXPLOSIONS)
B. W. Niebel *Professor Emeritus of Industrial Engineering, The Pennsylvania State University* (INDUSTRIAL ECONOMICS AND MANAGEMENT)
Paul E. Norian *Special Assistant, Regulatory Applications, Office of Nuclear Regulatory Research, U.S. Nuclear Regulatory Commission* (NUCLEAR POWER)
Nunzio J. Palladino* *Dean Emeritus, College of Engineering, Pennsylvania State University* (NUCLEAR POWER)
D. J. Patterson *Professor of Mechanical Engineering, Emeritus, University of Michigan* (INTERNAL COMBUSTION ENGINES)
Harold W. Paxton *United States Steel Professor Emeritus, Carnegie Mellon University* (IRON AND STEEL)
Richard W. Perkins *Professor of Mechanical, Aerospace, and Manufacturing Engineering, Syracuse University* (WOODCUTTING TOOLS AND MACHINES)
W. R. Perry* *University of Cincinnati* (ORBITAL MECHANICS. SPACE-VEHICLE TRAJECTORIES, FLIGHT MECHANICS, AND PERFORMANCE)
Kenneth A. Phair *Senior Mechanical Engineer, Stone and Webster Engineering Corp.* (GEOTHERMAL POWER)
Orvis E. Pigg *Section Head, Structural Analysis, Johnson Space Center, NASA* (SPACE-VEHICLE STRUCTURES)
Henry O. Pohl *Chief, Propulsion and Power Division, Johnson Space Center, NASA* (SPACE PROPULSION)
Charles D. Potts *Retired Project Engineer, Engineering Department, E. I. du Pont de Nemours & Co.* (ELECTRICAL ENGINEERING)
R. Ramakumar *Professor of Electrical Engineering, Oklahoma State University* (WIND POWER)
Pascal M. Rapier *Scientist III, Retired, Lawrence Berkeley Laboratory* (ENVIRONMENTAL CONTROL. OCCUPATIONAL SAFETY AND HEALTH. FIRE PROTECTION)
James D. Redmond *President, Technical Marketing Services, Inc.* (STAINLESS STEEL)
Albert H. Reinhardt *Technical Staff, Pratt & Whitney, Division of United Technologies Corp.* (GAS TURBINES)
Warren W. Rice *Senior Project Engineer, Piedmont Engineering Corp.* (MECHANICAL REFRIGERATION)
George J. Roddam *Sales Engineer, Lectromelt Furnace Division, Salem Furnace Co.* (ELECTRIC FURNACES AND OVENS)
Louis H. Roddis* *Late Consulting Engineer, Charleston, SC* (NUCLEAR POWER)
Darrold E. Roen *Late Manager, Sales & Special Engineering & Government Products, John Deere* (OFF-HIGHWAY VEHICLES)
Ivan L. Ross* *International Manager, Chain Conveyor Division, ACCO* (OVERHEAD CONVEYORS)
Robert J. Ross *Supervisory Research General Engineer, Forest Products Lab., USDA* (WOOD)
J. W. Russell* *University of Cincinnati* (SPACE-VEHICLE TRAJECTORIES, FLIGHT MECHANICS, AND PERFORMANCE. LUNAR- AND INTERPLANETARY-FLIGHT MECHANICS)
A. J. Rydzewski *Project Engineer, Engineering Department, E. I. du Pont de Nemours & Co.* (MECHANICAL REFRIGERATION)

C. Edward Sandifer *Professor, Western Connecticut State University, Danbury, CT* (MATHEMATICS)
Adel F. Sarofim *Lammot du Pont Professor of Chemical Engineering, Massachusetts Institute of Technology* (RADIANT HEAT TRANSFER)
Martin D. Schlesinger *Wallingford Group, Ltd.* (FUELS)
John R. Schley *Manager, Technical Marketing, RMI Titanium Co.* (TITANIUM AND ZIRCONIUM)
Matthew S. Schmidt *Senior Engineer, Rockwell Aerospace* (DOCKING OF TWO FREE-FLYING SPACECRAFT)
George Sege *Technical Assistant to the Director, Office of Nuclear Regulatory Research, U.S. Nuclear Regulatory Commission* (NUCLEAR POWER)
James D. Shearouse, III *Senior Development Engineer, The Dow Chemical Co.* (MAGNESIUM AND MAGNESIUM ALLOYS)
David A. Shifler *Metallurgist, Naval Surface Warfare Center* (CORROSION)
Rajiv Shivpuri *Professor of Industrial, Welding, and Systems Engineering, Ohio State University* (PLASTIC WORKING OF METALS)
William T. Simpson *Research Forest Products Technologist, Forest Products Lab., USDA* (WOOD)
Kenneth A. Smith *Edward R. Gilliland Professor of Chemical Engineering, Massachusetts Institute of Technology* (TRANSMISSION OF HEAT BY CONDUCTION AND CONVECTION)
Lawrence H. Sobel* *University of Cincinnati* (VIBRATION OF STRUCTURES)
James G. Speight *Western Research Institute* (FUELS)
Ivan K. Spiker *NASA, Retired* (STRUCTURAL COMPOSITES)
Robert D. Steele *Manager, Turbine and Rehabilitation Design, Voith Hydro, Inc.* (HYDRAULIC TURBINES)
Robert F. Steidel, Jr. *Professor of Mechanical Engineering, Retired, University of California, Berkeley* (MECHANICS OF SOLIDS)
Stephen R. Swanson *Professor of Mechanical Engineering, University of Utah* (FIBER COMPOSITE MATERIALS)
John Symonds *Fellow Engineer, Retired, Oceanic Division, Westinghouse Electric Corp.* (MECHANICAL PROPERTIES OF MATERIALS)
Anton TenWolde *Research Physicist, Forest Products Lab., USDA* (WOOD)
W. David Teter *Professor of Civil Engineering, University of Delaware* (SURVEYING)
Helmut Thielsch* *President, Thielsch Engineering Associates* (PIPE, PIPE FITTINGS, AND VALVES)
Michael C. Tracy *Captain, U.S. Navy* (MARINE ENGINEERING)
John H. Tundermann *Vice President, Research and Technology, INCO Alloys Intl., Inc.* (METALS AND ALLOYS FOR USE AT ELEVATED TEMPERATURES. NICKEL AND NICKEL ALLOYS)
Charles O. Velzy *Consultant* (INCINERATION)
Harry C. Verakis *Supervisory Physical Scientist, U.S. Department of Labor, Mine Safety and Health Administration* (DUST EXPLOSIONS)
Arnold S. Vernick *Associate, Geraghty & Miller, Inc.* (WATER)
J. P. Vidosic *Regents' Professor Emeritus of Mechanical Engineering, Georgia Institute of Technology* (MECHANICS OF MATERIALS)
Robert J. Vondrasek *Assistant Vice President of Engineering, National Fire Protection Assoc.* (COST OF ELECTRIC POWER)
Michael W. Washo *Engineering Associate, Eastman Kodak Co.* (BEARINGS WITH ROLLING CONTACT)
Harold M. Werner* *Consultant* (PAINTS AND PROTECTIVE COATINGS)
Robert H. White *Supervisory Wood Scientist, Forest Products Lab., USDA* (WOOD)
Thomas W. Wolff *Instructor, Retired, Mechanical Engineering Dept., The City College, The City University of New York* (SURFACE TEXTURE DESIGNATION, PRODUCTION, AND CONTROL)
John W. Wood, Jr. *Applications Specialist, Fluidtec Engineered Products, Coltec Industries* (PACKINGS AND SEALS)

Dedication

On the occasion of the publication of the tenth edition of *Marks' Standard Handbook for Mechanical Engineers,* we note that this is also the eightieth anniversary of the publication of the first edition. The Editors and publisher proffer this brief dedication to all those who have been instrumental in the realization of the goals set forth by Lionel S. Marks in the preface to the first edition.

First, we honor the memory of the deceased Editors, Lionel S. Marks and Theodore Baumeister. Lionel S. Marks' concept of a *Mechanical Engineers' Handbook* came to fruition with the publication of the first edition in 1916; Theodore Baumeister followed as Editor with the publication of the sixth edition in 1958.

Second, we are indebted to our contributors, past and present, who so willingly mined their expertise to gather material for inclusion in the Handbook, thereby sharing it with others, far and wide.

Third, we acknowledge our wide circle of readers—engineers and others—who have used the Handbook in the conduct of their work and, from time to time, have provided cogent commentary, suggestions, and expressions of loyalty.

Preface to the Tenth Edition

In the preparation of the tenth edition of ''Marks,'' the Editors had two major continuing objectives. First, to modernize and update the contents as required, and second, to hold to the high standard maintained for eighty years by the previous Editors, Lionel S. Marks and Theodore Baumeister.

The Editors have found it instructive to leaf through the first edition of *Marks' Handbook* and to peruse its contents. Some topics still have currency as we approach the end of the twentieth century; others are of historical interest only. Certainly, the passage of 80 years since the publication of the first edition sends a clear message that ''things change''!

The replacement of the U.S. Customary System (USCS) of units by the International System (SI) is still far from complete, and proceeds at different rates not only in the engineering professions, but also in our society in general. Accordingly, duality of units has been retained, as appropriate.

Established practice combined with new concepts and developments are the underpinnings of our profession. Among the most significant and far-reaching changes are the incorporation of microprocessors into many tools and devices, both new and old. An ever-increasing number of production processes are being automated with robots performing dull or dangerous jobs.

Workstations consisting of personal computers and a selection of software seemingly without limits are almost universal. Not only does the engineer have powerful computational and analytical tools at hand, but also those same tools have been applied in diverse areas which appear to have no bounds. A modern business or manufacturing entity without a keyboard and a screen is an anomaly.

The Editors are cognizant of the competing requirements to offer the user a broad spectrum of information that has been the hallmark of the Marks' Handbook since its inception, and yet to keep the size of the one volume within reason. This has been achieved through the diligent efforts and cooperation of contributors, reviewers, and the publisher.

Last, the Handbook is ultimately the responsibility of the Editors. Meticulous care has been exercised to avoid errors, but if any are inadvertently included, the Editors will appreciate being so informed so that corrections can be incorporated in subsequent printings of this edition.

Ardsley, NY — EUGENE A. AVALLONE
Newark, DE — THEODORE BAUMEISTER III

Preface to the First Edition*

This Handbook is intended to supply both the practicing engineer and the student with a reference work which is authoritative in character and which covers the field of mechanical engineering in a comprehensive manner. It is no longer possible for a single individual or a small group of individuals to have so intimate an acquaintance with any major division of engineering as is necessary if critical judgment is to be exercised in the statement of current practice and the selection of engineering data. Only by the cooperation of a considerable number of specialists is it possible to obtain the desirable degree of reliability. This Handbook represents the work of fifty specialists.

Each contributor is to be regarded as responsible for the accuracy of his section. The number of contributors required to ensure sufficiently specialized knowledge for all the topics treated is necessarily large. It was found desirable to enlist the services of thirteen specialists for an adequate handling of the ''Properties of Engineering Materials.'' Such topics as ''Automobiles,'' ''Aeronautics,'' ''Illumination,'' ''Patent Law,'' ''Cost Accounting,'' ''Industrial Buildings,'' ''Corrosion,'' ''Air Conditioning,'' ''Fire Protection,'' ''Prevention of Accidents,'' etc., though occupying relatively small spaces in the book, demanded each a separate writer.

A number of the contributions which deal with engineering practice, after examination by the Editor-in-Chief, were submitted by him to one or more specialists for criticism and suggestions. Their cooperation has proved of great value in securing greater accuracy and in ensuring that the subject matter does not embody solely the practice of one individual but is truly representative.

An accuracy of four significant figures has been assumed as the desirable limit; figures in excess of this number have been deleted, except in special cases. In the mathematical tables only four significant figures have been kept.

The Editor-in-Chief desires to express here his appreciation of the spirit of cooperation shown by the Contributors and of their patience in submitting to modifications of their sections. He wishes also to thank the Publishers for giving him complete freedom and hearty assistance in all matters relating to the book from the choice of contributors to the details of typography.

Cambridge, Mass.
April 23, 1916

LIONEL S. MARKS

* Excerpt.

Symbols and Abbreviations

For symbols of chemical elements, see Sec. 6; for abbreviations applying to metric weights and measures and SI units, Sec. 1; SI unit prefixes are listed on p. 1-19.

Pairs of parentheses, brackets, etc., are frequently used in this work to indicate corresponding values. For example, the statement that ''the cost per kW of a 30,000-kW plant is $86; of a 15,000-kW plant, $98; and of an 8,000-kW plant, $112,'' is condensed as follows: The cost per kW of a 30,000 (15,000) [8,000]-kW plant is $86 (98) [112].

In the citation of references readers should always attempt to consult the latest edition of referenced publications.

A or Å	Angstrom unit = 10^{-10} m; 3.937×10^{-11} in
A	mass number = N + Z; ampere
AA	arithmetical average
AAA	Am. Automobile Assoc.
AAMA	American Automobile Manufacturers' Assoc.
AAR	Assoc. of Am. Railroads
AAS	Am. Astronautical Soc.
ABAI	Am. Boiler & Affiliated Industries
abs	absolute
a.c.	aerodynamic center
a-c, ac	alternating current
ACI	Am. Concrete Inst.
ACM	Assoc. for Computing Machinery
ACRMA	Air Conditioning and Refrigerating Manufacturers Assoc.
ACS	Am. Chemical Soc.
ACSR	aluminum cable steel-reinforced
ACV	air cushion vehicle
A.D.	anno Domini (in the year of our Lord)
AEC	Atomic Energy Commission (U.S.)
a-f, af	audio frequency
AFBMA	Anti-friction Bearings Manufacturers' Assoc.
AFS	Am. Foundrymen's Soc.
AGA	Am. Gas Assoc.
AGMA	Am. Gear Manufacturers' Assoc.
ahp	air horsepower
AlChE	Am. Inst. of Chemical Engineers
AIEE	Am. Inst. of Electrical Engineers (see IEEE)
AIME	Am. Inst. of Mining Engineers
AIP	Am. Inst. of Physics
AISC	American Institute of Steel Construction, Inc.
AISE	Am. Iron & Steel Engineers
AISI	Am. Iron and Steel Inst.
a.m.	ante meridiem (before noon)
a-m, am	amplitude modulation
Am. Mach.	Am. Machinist (New York)
AMA	Acoustical Materials Assoc.
AMCA	Air Moving & Conditioning Assoc., Inc.
amu	atomic mass unit
AN	ammonium nitrate (explosive); Army-Navy Specification
AN-FO	ammonium nitrate-fuel oil (explosive)
ANC	Army-Navy Civil Aeronautics Committee
ANS	Am. Nuclear Soc.
ANSI	American National Standards Institute
antilog	antilogarithm of
API	Am. Petroleum Inst.
approx	approximately
APWA	Am. Public Works Assoc.
AREA	Am. Railroad Eng. Assoc.
ARI	Air Conditioning and Refrigeration Inst.
ARS	Am. Rocket Soc.
ASCE	Am. Soc. of Civil Engineers
ASHRAE	Am. Soc. of Heating, Refrigerating, and Air Conditioning Engineers
ASLE	Am. Soc. of Lubricating Engineers
ASM	Am. Soc. of Metals
ASME	Am. Soc. of Mechanical Engineers
ASST	Am. Soc. of Steel Treating
ASTM	Am. Soc. for Testing and Materials
ASTME	Am. Soc. of Tool & Manufacturing Engineers
atm	atmosphere
Auto. Ind.	Automotive Industries (New York)
avdp	avoirdupois
avg, ave	average
AWG	Am. Wire Gage
AWPA	Am. Wood Preservation Assoc.
AWS	American Welding Soc.
AWWA	American Water Works Assoc.
b	barns
bar	barometer
B&S	Brown & Sharp (gage); Beams and Stringers
bbl	barrels
B.C.	before Christ
B.C.C.	body centered cubic
Bé	Baumé (degrees)
B.G.	Birmingham gage (hoop and sheet)
bgd	billions of gallons per day
BHN	Brinnell Hardness Number
bhp	brake horsepower
BLC	boundary layer control
B.M.	board measure; bench mark
bmep	brake mean effective pressure
B of M, BuMines	Bureau of Mines
BOD	biochemical oxygen demand

bp	boiling point
Bq	bequerel
bsfc	brake specific fuel consumption
BSI	British Standards Inst.
Btu	British thermal units
Btuh, Btu/h	Btu per hr
bu	bushels
Bull.	Bulletin
Buweaps	Bureau of Weapons, U.S. Navy
BWG	Birmingham wire gage
c	velocity of light
°C	degrees Celsius (centigrade)
C	coulomb
CAB	Civil Aeronautics Board
CAGI	Compressed Air & Gas Inst.
cal	calories
C-B-R	chemical, biological & radiological (filters)
CBS	Columbia Broadcasting System
cc, cm^3	cubic centimeters
CCR	critical compression ratio
c to c	center to center
cd	candela
c.f.	centrifugal force
cf.	confer (compare)
cfh, ft^3/h	cubic feet per hour
cfm, ft^3/min	cubic feet per minute
C.F.R.	Cooperative Fuel Research
cfs, ft^3/s	cubic feet per second
cg	center of gravity
cgs	centimeter-gram-second
Chm. Eng.	Chemical Eng'g (New York)
chu	centrigrade heat unit
C.I.	cast iron
cir	circular
cir mil	circular mils
cm	centimeters
CME	Chartered Mech. Engr. (IMechE)
C.N.	cetane number
coef	coefficient
COESA	U.S. Committee on Extension to the Standard Atmosphere
col	column
colog	cologarithm of
const	constant
cos	cosine of
$\cos^{-1}$	angle whose cosine is, inverse cosine of
cosh	hyperbolic cosine of
$\cosh^{-1}$	inverse hyperbolic cosine of
cot	cotangent of
$\cot^{-1}$	angle whose cotangent is (see $\cos^{-1}$)
coth	hyperbolic cotangent of
$\coth^{-1}$	inverse hyperbolic cotangent of
covers	coversed sine of
c.p.	circular pitch; center of pressure
cp	candle power
cp	coef of performance
CP	chemically pure
CPH	close packed hexagonal
cpm, cycles/min	cycles per minute
cps, cycles/s	cycles per second
CSA	Canadian Standards Assoc.
csc	cosecant of
$\csc^{-1}$	angle whose cosecant is (see $\cos^{-1}$)
csch	hyperbolic cosecant of
csch^{-1}	inverse hyperbolic cosecant of
cu	cubic
cyl	cylinder
db, dB	decibel
d-c, dc	direct current
def	definition
deg	degrees
diam. (dia)	diameter
DO	dissolved oxygen
D_2O	deuterium (heavy water)
d.p.	double pole
DP	Diametral pitch
DPH	diamond pyramid hardness
DST	daylight saving time
d^2 tons	breaking strength, d = chain wire diam, in.
DX	direct expansion
e	base of Napierian logarithmic system (= 2.7182 +)
EAP	equivalent air pressure
EDR	equivalent direct radiation
EEI	Edison Electric Inst.
eff	efficiency
e.g.	exempli gratia (for example)
ehp	effective horsepower
EHV	extra high voltage
El. Wld.	Electrical World (New York)
elec	electric
elong	elongation
emf	electromotive force
Engg.	Engineering (London)
Engr.	The Engineer (London)
ENT	emergency negative thrust
EP	extreme pressure (lubricant)
ERDA	Energy Research & Development Administration (successor to AEC; see also NRC)
Eq.	equation
est	estimated
etc.	et cetera (and so forth)
et seq.	et sequens (and the following)
eV	electron volts
evap	evaporation
exp	exponential function of
exsec	exterior secant of
ext	external
°F	degrees Fahrenheit
F	farad
FAA	Federal Aviation Agency
F.C.	fixed carbon, %
FCC	Federal Communications Commission; Federal Constructive Council
F.C.C.	face-centered-cubic (alloys)
ff.	following (pages)
fhp	friction horsepower
Fig.	figure
F.I.T.	Federal income tax
f-m, fm	frequency modulation
F.O.B.	free on board (cars)
FP	fore perpendicular
FPC	Federal Power Commission
fpm, ft/min	feet per minute
fps	foot-pound-second system
ft/s	feet per second
F.S.	Federal Specifications
FSB	Federal Specifications Board
fsp	fiber saturation point
ft	feet
fc	foot candles
fL	foot lamberts
ft · lb	foot-pounds
g	acceleration due to gravity
g	grams
gal	gallons
gc	gigacycles per sec

GCA	ground-controlled approach
g · cal	gram-calories
gd	Gudermannian of
G.E.	General Electric Co.
GEM	ground effect machine
GFI	gullet feed index
G.M.	General Motors Co.
GMT	Greenwich Mean Time
GNP	gross national product
gpcd	gallons per capita day
gpd	gallons per day; grams per denier
gpm, gal/min	gallons per minute
gps, gal/s	gallons per second
gpt	grams per tex
H	henry
h	Planck's constant = 6.624×10^{-27} erg-sec
$\hbar$	Planck's constant, $\hbar = h/2\pi$
HEPA	high efficiency particulate matter
h-f, hf	high frequency
hhv	high heat value
horiz	horizontal
hp	horsepower
h-p	high-pressure
HPAC	Heating, Piping, & Air Conditioning (Chicago)
hp · hr	horsepower-hour
hr, h	hours
HSS	high speed steel
H.T.	heat-treated
HTHW	high temperature hot water
Hz	hertz = 1 cycle/s (cps)
IACS	International Annealed Copper Standard
IAeS	Institute of Aerospace Sciences
ibid.	ibidem (in the same place)
ICAO	International Civil Aviation Organization
ICC	Interstate Commerce Commission
ICE	Inst. of Civil Engineers
ICI	International Commission on Illumination
I.C.T.	International Critical Tables
I.D., ID	inside diameter
i.e.	id est (that is)
IEC	International Electrotechnical Commission
IEEE	Inst. of Electrical & Electronics Engineers (successor to AIEE, *q.v.*)
IES	Illuminating Engineering Soc.
i-f, if	intermediate frequency
IGT	Inst. of Gas Technology
ihp	indicated horsepower
IMechE	Inst. of Mechanical Engineers
imep	indicated mean effective pressure
Imp	Imperial
in., in	inches
in. · lb, in · lb	inch-pounds
INA	Inst. of Naval Architects
Ind. & Eng. Chem.	Industrial & Eng'g Chemistry (Easton, PA)
int	internal
i-p, ip	intermediate pressure
ipm, in/min	inches per minute
ipr	inches per revolution
IPS	iron pipe size
IRE	Inst. of Radio Engineers (see IEEE)
IRS	Internal Revenue Service
ISO	International Organization for Standardization
isoth	isothermal
ISTM	International Soc. for Testing Materials
IUPAC	International Union of Pure & Applied Chemistry
J	joule
J&P	joists and planks
Jour.	Journal
JP	jet propulsion fuel
k	isentropic exponent; conductivity
K	degrees Kelvin (Celsius abs)
K	Knudsen number
kB	kilo Btu (1000 Btu)
kc	kilocycles
kcps	kilocycles per sec
kg	kilograms
kg · cal	kilogram-calories
kg · m	kilogram-meters
kip	1000 lb or 1 kilo-pound
kips	thousands of pounds
km	kilometers
kmc	kilomegacycles per sec
kmcps	kilomegacycles per sec
kpsi	thousands of pounds per sq in
ksi	one kip per sq in, 1000 psi (lb/in^2)
kts	knots
kVA	kilovolt-amperes
kW	kilowatts
kWh	kilowatt-hours
L	lamberts
l, L	litres
£	Laplace operational symbol
lb	pounds
L.B.P.	length between perpendiculars
lhv	low heat value
lim	limit
lin	linear
ln	Napierian logarithm of
loc. cit.	loco citato (place already cited)
log	common logarithm of
LOX	liquid oxygen explosive
l-p, lp	low pressure
LPG	liquified petroleum gas
lpw, lm/W	lumens per watt
lx	lux
L.W.L.	load water line
lm	lumen
m	metres
M	thousand; Mach number; moisture, %
mA	milliamperes
Machy.	Machinery (New York)
max	maximum
MBh	thousands of Btu per hr
mc	megacycles per sec
m.c.	moisture content
Mcf	thousand cubic feet
mcps	megacycles per sec
Mech. Eng.	Mechanical Eng'g (ASME)
mep	mean effective pressure
METO	maximum, except during take-off
me V	million electron volts
MF	maintenance factor
mhc	mean horizontal candles
mi	mile
MIL-STD	U.S. Military Standard
min	minutes; minimum
mip	mean indicated pressure
MKS	meter-kilogram-second system
MKSA	meter-kilogram-second-ampere system
mL	millilamberts
ml, mL	millilitre = 1.000027 cm^3
mlhc	mean lower hemispherical candles
mm	millimetres
mm-free	mineral matter free

mmf	magnetomotive force
mol	mole
mp	melting point
MPC	maximum permissible concentration
mph, mi/h	miles per hour
MRT	mean radiant temperature
ms	manuscript; milliseconds
msc	mean spherical candles
MSS	Manufacturers Standardization Soc. of the Valve & Fittings Industry
Mu	micron, micro
MW	megawatts
MW day	megawatt day
MWT	mean water temperature
n	polytropic exponent
N	number (in mathematical tables)
N	number of neutrons; newton
N_s	specific speed
NA	not available
NAA	National Assoc. of Accountants
NACA	National Advisory Committee on Aeronautics (see NASA)
NACM	National Assoc. of Chain Manufacturers
NASA	National Aeronautics and Space Administration
nat.	natural
NBC	National Broadcasting Company
NBFU	National Board of Fire Underwriters
NBS	National Bureau of Standards
NCN	nitrocarbonitrate (explosive)
NDHA	National District Hearing Assoc.
NEC®	National Electric Code® (National Electrical Code® and NEC® are registered trademarks of the National Fire Protection Association, Inc., Quincy, MA.)
NEMA	National Electrical Manufacturers Assoc.
NFPA	National Fire Protection Assoc.
NLGI	National Lubricating Grease Institute
nm	nautical miles
No. (Nos.)	number(s)
NPSH	net positive suction head
NRC	Nuclear Regulator Commission (successor to AEC; see also ERDA)
NTP	normal temperature and pressure
O.D., OD	outside diameter (pipes)
O.H.	open-hearth (steel)
O.N.	octane number
op. cit.	opere citato (work already cited)
OSHA	Occupational Safety & Health Administration
OSW	Office of Saline Water
OTS	Office of Technical Services, U.S. Dept. of Commerce
oz	ounces
p. (pp.)	page (pages)
Pa	pascal
P.C.	propulsive coefficient
PE	polyethylene
PEG	polyethylene glycol
P.E.L.	proportional elastic limit
PETN	an explosive
pf	power factor
PFI	Pipe Fabrication Inst.
PIV	peak inverse voltage
p.m.	post meridiem (after noon)
PM	preventive maintenance
P.N.	performance number
ppb	parts per billion
PPI	plan position indicator
ppm	parts per million
press	pressure
Proc.	Proceedings
PSD	power spectral density, g^2/cps
psi, lb/in^2	lb per sq in
psia	lb per sq in. abs
psig	lb per sq in. gage
pt	point; pint
PVC	polyvinyl chloride
Q	10^{18} Btu
qt	quarts
q.v.	quod vide (which see)
r	roentgens
R	gas constant
R	deg Rankine (Fahrenheit abs); Reynolds number
rad	radius; radiation absorbed dose; radian
RBE	see rem
R-C	resistor-capacitor
RCA	Radio Corporation of America
R&D	research & development
RDX	cyclonite, a military explosive
rem	Roentgen equivalent man (formerly RBE)
rev	revolutions
r-f, rf	radio frequency
RMA	Rubber Manufacturers Assoc.
rms	square root of mean square
rpm, r/min	revolutions per minute
rps, r/s	revolutions per second
RSHF	room sensible heat factor
ry.	railway
s	entropy
s	seconds
S	sulfur, %; siemens
SAE	Soc. of Automotive Engineers
sat	saturated
SBI	steel Boiler Inst.
scfm	standard cu ft per min
SCR	silicon controlled rectifier
sec	secant of
sec^{-1}	angle whose secant is (see $\cos^{-1}$)
Sec.	Section
sech	hyperbolic secant of
$sech^{-1}$	inverse hyperbolic secant of
segm	segment
SE No.	steam emulsion number
sfc	specific fuel consumption, lb per hphr
sfm, sfpm	surface feet per minute
shp	shaft horsepower
SI	International System of Units (Le Système International d'Unites)
sin	sine of
sin^{-1}	angle whose sine is (see $\cos^{-1}$)
sinh	hyperbolic sine of
$sinh^{-1}$	inverse hyperbolic sine of
SME	Society of Manufacturing Engineers (successor to ASTME)
SNAME	Soc. of Naval Architects and Marine Engineers
SP	static pressure
sp	specific
specif	specification
sp gr	specific gravity
sp ht	specific heat
spp	species unspecified (botanical)
SPS	standard pipe size
sq	square
sr	steradian
SSF	sec Saybolt Furol
SSU	seconds Saybolt Universal (same as SUS)
std	standard
SUS	Saybolt Universal seconds (same as SSU)
SWG	Standard (British) wire gage
T	tesla

TAC	Technical Advisory Committee on Weather Design Conditions (ASHRAE)
tan	tangent of
$\tan^{-1}$	angle whose tangent is (see $\cos^{-1}$)
tanh	hyperbolic tangent of
$\tanh^{-1}$	inverse hyperbolic tangent of
TDH	total dynamic head
TEL	tetraethyl lead
temp	temperature
THI	temperature-humidity (discomfort) index
thp	thrust horsepower
TNT	trinitrotoluol (explosive)
torr	= 1 mm Hg = 1.332 millibars (1/760) atm = (1.013250/760) dynes per cm^2
TP	total pressure
tph	tons per hour
tpi	turns per in
TR	transmitter-receiver
Trans.	Transactions
T.S.	tensile strength; tensile stress
tsi	tons per sq in
ttd	terminal temperature difference
UHF	ultra high frequency
UKAEA	United Kingdom Atomic Energy Authority
UL	Underwriters' Laboratory
ult	ultimate
UMS	universal maintenance standards
USAF	U.S. Air Force
USCG	U.S. Coast Guard
USCS	U.S. Commercial Standard; U.S. Customary System
USDA	U.S. Dept. of Agriculture
USFPL	U.S. Forest Products Laboratory
USGS	U.S. Geologic Survey
USHEW	U.S. Dept. of Health, Education & Welfare
USN	U.S. Navy
USP	U.S. Pharmacopoeia
USPHS	U.S. Public Health Service
USS	United States Standard
USSG	U.S. Standard Gage
UTC	Coordinated Universal Time
V	volt
VCF	visual comfort factor
VCI	visual comfort index
VDI	Verein Deutscher Ingenieure
vel	velocity
vers	versed sine of
vert	vertical
VHF	very high frequency
VI	viscosity index
viz.	videlicet (namely)
V.M.	volatile matter, %
vol	volume
VP	velocity pressure
vs.	versus
W	watt
Wb	weber
W&M	Washburn & Moen wire gage
w.g.	water gage
WHO	World Health Organization
W.I.	wrought iron
W.P.A.	Western Pine Assoc.
wt	weight
yd	yards
Y.P.	yield point
yr	year(s)
Y.S.	yield strength; yield stress
z	atomic number; figure of merit
Zeit.	Zeitschrift
Δ	mass defect
μc	microcurie
σ, s	Boltzmann constant
μ	micro ($= 10^{-6}$), as in μs
μm	micrometer (micron) = 10^{-6} m (10^{-3} mm)
Ω	ohm

MATHEMATICAL SIGNS AND SYMBOLS

$+$	plus (sign of addition)
$+$	positive
$-$	minus (sign of subtraction)
$-$	negative
$\pm$ ($\mp$)	plus or minus (minus or plus)
$\times$	times, by (multiplication sign)
$\cdot$	multiplied by
$\div$	sign of division
/	divided by
:	ratio sign, divided by, is to
::	equals, as (proportion)
$<$	less than
$>$	greater than
$\ll$	much less than
$\gg$	much greater than
$=$	equals
$\equiv$	identical with
$\sim$	similar to
$\approx$	approximately equals
$\cong$	approximately equals, congruent
$\leqslant$	qual to or less than
$\geqslant$	equal to or greater than
$\neq$ $\neq$	not equal to
$\rightarrow \doteq$	approaches
$\propto$	varies as
∞	infinity
$\sqrt{\ }$	square root of
$\sqrt[3]{\ }$	cube root of
$\therefore$	therefore
$\parallel$	parallel to
() [] {}	parentheses, brackets and braces; quantities enclosed by them to be taken together in multiplying, dividing, etc.
$\overline{AB}$	length of line from A to B
π	pi ($= 3.14159^{+}$)
$^\circ$	degrees
$'$	minutes
$''$	seconds
$\angle$	angle
dx	differential of x
Δ	(delta) difference
Δx	increment of x
$\partial u/\partial x$	partial derivative of u with respect to x
$\int$	integral of

$\int_b^a$	integral of, between limits a and b
$\oint$	line integral around a closed path
Σ	(sigma) summation of
$f(x)$, $F(x)$	functions of x
$\exp x = e^x$	[$e = 2.71828$ (base of natural, or Napierian, logarithms)]
∇	del or nabla, vector differential operator
∇^2	Laplacian operator
£	Laplace operational symbol
$4!$	factorial $4 = 4 \times 3 \times 2 \times 1$
$\lvert x \rvert$	absolute value of x
$\dot{x}$	first derivative of x with respect to time
$\ddot{x}$	second derivative of x with respect to time
$\mathbf{A} \times \mathbf{B}$	vector product; magnitude of **A** times magnitude of **B** times sine of the angle from **A** to **B**; $AB \sin \overline{AB}$
$\mathbf{A} \cdot \mathbf{B}$	scalar product; magnitude of **A** times magnitude of **B** times cosine of the angle from **A** to **B**; $AB \cos \overline{AB}$