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McGRAW-HILL'S ENGINEERING COMPANION

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PREFACE

The scores of literature materials available to engineers of today are both vast and impressive. Specialized studies, textbooks, encyclopedias, pocket books of frequently used formulas, and collections of tables, data and conversion charts and, of course, handbooks clutter the bookshelves of libraries and homes. All of these serve a common purpose: to provide information or necessary solutions to problems various or specific. With the new *McGraw-Hill's Engineering Companion*, we make a bold step toward adding yet another work to this well established list and an even bolder claim that this work will soon stand on a new list on its own: A list of one.

How do we find the information we seek, the solution we need, without conducting a large survey through engineering literature? How do we allow engineers to work more on concepts and less on information quests? The scope of this book is defined precisely in answer to these needs. In one volume, essentials of engineering sciences, concise selection of engineering data, and surveys for use in both design and everyday practice are gathered together to help both students and experts navigate their way through challenges ahead. *McGraw-Hill's Engineering Companion* is one volume of manageable size that will soon become the irreplaceable aid for engineers of the twenty-first century.

While preparing the data for the *McGraw-Hill's Engineering Companion* we considered the everyday needs of engineers working on design, product development, applied research, production, installation service, engineering consulting, sales and regulations. We gathered material ready to use for most application-oriented problems and/or theory based calculations. In result, this volume addresses engineering needs both where the user possesses abstract and/or concrete competence. It is in the true sense *the engineer's companion* in every situation.

For students of engineering, the *Companion* illustrates all avenues of engineering world as well as the essence of each topic in the field of engineering. It is an extremely useful tool in completion of student design projects (especially if one holds a summer job!). The *Companion* further allows consulting engineers to quickly position themselves toward the solution of an imposed problem.

Covering every frequently used topic in engineering science, and presenting all engineering data needed in most common applications (including key methods and tools), basic core material of every engineering branch has also been given. This book is a compact but comprehensive source for both the "old-school" and the new generation of engineers, working across the traditional discipline lines.

As is the case with all professional activities including engineering, nothing can take the place of common sense and an inquiring mind. This reference is geared to provide the necessary information, in order to save time for professional judgment and creativity. The *Companion* is the place to *turn first* for all practical advice and quick answers through all phases of working on a specific task in engineering.

The art of writing lies in the ability to edit your work. A competent writer is not the one who manages to include all, but the one who chooses well. After thoroughly researching the acclaimed collection of McGraw-Hill publications in the

field of engineering and following that, related literature from publishers worldwide; after utilizing the expertise of many authors, contributors, and editors; we can say that we chose well. Many worked-out examples, a systematic collection of data in the form of tables and diagrams, a collection of clear illustrations, key methods, and tools in every field of engineering are contained in this volume. It should be noted that from the bulk of materials from a variety of sources, only *the tested facts* of engineering and engineering science were included in this book.

McGraw-Hill's Engineering Companion is as easy to use as it is well laid out, with clear chapter division, clear and uniformly outlined contents for each chapter, and in addition, most chapters ending with a nomenclature section that includes a list of all symbols and their SI units.

We did our best to achieve an error-free publication, despite the magnitude of the volume and the amount of information contained within it. Accordingly, we would appreciate being informed of any errors and receiving opinions on deficiencies detected and possible improvements so that these may be amended/included in subsequent printings and future editions.

Ejup N. Ganić

Tyler G. Hicks

ACKNOWLEDGMENTS

Parts of this book were drawn from McGraw-Hill books published over the past several decades. Priority and emphasis was given to the most recent editions of these works. Collections of McGraw-Hill handbooks, specialized technical books, textbooks, pocket books, manuals, encyclopedias, etc., have been thoroughly surveyed for material analysis and selections for this book. This was the main source of literature used. The material drawn is updated and revised.

Proper acknowledgment and/or reference for every source used are given either on the specific page on which the source is used, as an end-of-chapter note, or in the reference list.

Related literature from other publishers worldwide was also surveyed in our attempt to provide the reader with the most competent and complete presentation of material. These works were used for comparison and in order to aid clarity of presentation. All instances where the works in question were used were also properly cited and referenced.

We are grateful to many authors, contributors and editors whose work was used both directly and indirectly within this book. The new generation of engineers will certainly benefit from the contribution of these experts.

We wish to acknowledge specifically the work of Myke Predko, to whom we owe all sections of this volume concerned with electrical and electronic engineering.

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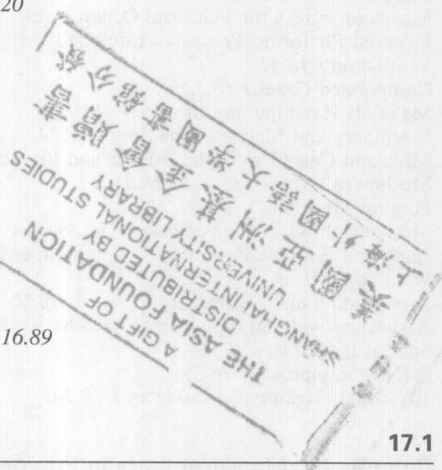
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CHAPTER 1

ENGINEERING UNITS

DIMENSIONS AND UNITS

There are as many *dimensions* as there are kinds of physical quantities. Each new physical quantity gives rise to a new dimension. There can be only one dimension for each physical quantity.

A *unit* is a particular amount of the physical quantity. There are infinite possibilities for choosing a unit of a single physical quantity. All the possible units of the same physical quantity must be related by purely numerical factors.

Derived units are algebraic combinations of base units with some of the combinations being assigned special names and symbols.

SYSTEMS OF UNITS

There are still several systems of common units in use throughout the world. Transition from the others to *Système International d'Unités* (International System of Units), or SI, will proceed at a rational pace to accommodate the needs of the professions or industries involved and the public. The transition period will be long and complex, and duality of units probably will be demanded for at least a decade after the change is introduced.

1. SI Units. In October 1960, the Eleventh General (International) Conference on Weights and Measures redefined some of the original metric units and expanded the SI system to include other physical and engineering units.

The Metric Conversion Act of 1975 codifies the voluntary conversion of the United States to the SI system. It is expected that in time all units used in the United States will be in SI. For that reason, this chapter includes tables showing SI units, prefixes, and equivalents.

SI consists of seven base units, two supplementary units, a series of derived units consistent with the base and supplementary units, and a series of approved prefixes for the formation of multiples and submultiples of the various units. Multiple and submultiple prefixes in steps of 1000 are recommended.

Table 1.1 shows SI base and supplementary quantities (dimensions) and units. Tables 1.2 and 1.3 and Fig. 1.1 include additional derived units of SI. Table 1.4 shows SI prefixes.

TABLE 1.1 SI Base and Supplementary Quantities and Units

Quantity or "dimension"	SI unit	SI unit symbol ("abbreviation");
Base quantity or "dimension"		
length	meter	m
mass	kilogram	kg
time	second	s
electric current	ampere	A
thermodynamic temperature	kelvin	K
amount of substance	mole	mol
luminous intensity	candela	cd
Supplementary quantity or "dimension"		
plane angle	radian	rad
solid angle	steradian	sr

Source: From Perry, Green, and Maloney.¹

TABLE 1.2 Derived Units of SI which Have Special Names

Quantity	Unit	Symbol	Formula
frequency (of a periodic phenomenon)	hertz	Hz	1/s
force	newton	N	(kg·m)/s ²
pressure, stress	pascal	Pa	N/m ²
energy, work, quantity of heat	joule	J	N·m
power, radiant flux	watt	W	J/s
quantity of electricity, electric charge	coulomb	C	A·s
electric potential, potential	volt	V	W/A
difference, electromotive force			
capacitance	farad	F	C/V
electric resistance	ohm	Ω	V/A
conductance	siemens	S	A/V
magnetic flux	weber	Wb	V·s
magnetic-flux density	tesla	T	Wb/m ²
inductance	henry	H	Wb/A
luminous flux	lumen	lm	cd·sr
illuminance	lux	lx	lm/m ²
activity (of radionuclides)	becquerel	Bq	1/s
absorbed dose	gray	Gy	J/kg

Source: From Perry, Green, and Maloney.¹

2. U.S. Customary System Units. The U.S. Customary System (USCS) is the system of units most commonly used for measures of weight and length in the United States. They are identical for practical purposes with the corresponding English units (see Sec. 4), but the capacity measures differ from those now in use in the British Commonwealth, the U.S. gallon being defined as 231 in³ and the bushel as 2150.42 in³, whereas the corresponding British Imperial units are, respectively, 277.42 in³, and 2219.36 in³ (1 Imp gal = 1.2 U.S. gal, approx.; 1 Imp bu = 1.03 U.S. bu, approx.). Table 1.5a shows USCS units, the corresponding SI

TABLE 1.3 Additional Common Derived Units of SI

Quantity	Unit	Symbol
acceleration	meter per second squared	m/s ²
angular acceleration	radian per second squared	rad/s ²
angular velocity	radian per second	rad/s
area	square meter	m ²
concentration (of amount of substance)	mole per cubic meter	mol/m ³
current density	ampere per square meter	A/m ²
density, mass	kilogram per cubic meter	kg/m ³
electric-charge density	coulomb per cubic meter	C/m ³
electric-field strength	volt per meter	V/m
electric-flux density	coulomb per square meter	C/m ²
energy density	joule per cubic meter	J/m ³
entropy	joule per kelvin	J/K
heat capacity	joule per kelvin	J/K
heat-flux density	watt per square meter	W/m ²
irradiance		
luminance	candela per square meter	cd/m ²
magnetic-field strength	ampere per meter	A/m
molar energy	joule per mole	J/mol
molar entropy	joule per mole-kelvin	J/(mol·K)
molar-heat capacity	joule per mole-kelvin	J/(mol·K)
moment of force	newton-meter	N·m
permeability	henry per meter	H/m
permittivity	farad per meter	F/m
radiance	watt per square-meter steradian	W/(m ² ·sr)
radian intensity	watt per steradian	W/sr
specific-heat capacity	joule per kilogram-kelvin	J/(kg·K)
specific energy	joule per kilogram	J/kg
specific entropy	joule per kilogram-kelvin	J/(kg·K)
specific volume	cubic meter per kilogram	m ³ /kg
surface tension	newton per meter	N/m
thermal conductivity	watt per meter-kelvin	W/(m·K)
velocity	meter per second	m/s
viscosity, dynamic	pascal-second	Pa·s
viscosity, kinematic	square meter per second	m ² /s
volume	cubic meter	m ³
wave number	1 per meter	1/m

Source: From Perry, Green, and Maloney.¹

units, and the numerical factors used to convert USCS values into SI. Table 1.5b defines the abbreviations used.

3. Metric System of Units. In the United States, the *metric* is commonly taken to refer to a system of length and mass units developed in France about 1800. The unit of length was equal to 1/10,000,000 of a quarter meridian (north pole to equator) and named the *meter*. A cube 0.1 meter on a side was the *liter*, the unit of volume. The mass of water filling this cube was the *kilogram*, or standard of mass; i.e., 1 liter of water = 1 kilogram of mass. Metal bars and weights were constructed conforming to these prescriptions for the meter and kilogram. One bar