Pearson New International Edition

Principles of Electric Circuits
Conventional Current Version

Thomas L. Floyd

Ninth Edition

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QUANTITIES AND UNITS

CHAPTER OUTLINE

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CHAPTER OBJECTIVES

- Discuss the SI standard
- Use scientific notation (powers of ten) to represent quantities
- Use engineering notation and metric prefixes to represent large and small quantities
- Convert from one unit with a metric prefix to another
- Express measured data with the proper number of significant digits

KEY TERMS

- SI
- Scientific notation
- Power of ten
- Exponent
- Engineering notation
- Metric prefix
- Error
- Accuracy
- Precision
- Significant digits
- Round off

VISIT THE COMPANION WEBSITE

Study aids for this chapter are available at
http://www.pearsonhighered.com/floyd

INTRODUCTION

You must be familiar with the units used in electronics and know how to express electrical quantities in various ways using metric prefixes. Scientific notation and engineering notation are indispensable tools whether you use a computer, a calculator, or do computations the old-fashioned way.

SAFETY NOTE

When you work with electricity, you must always consider safety first. Safety notes remind you of the importance of safety and provide tips for a safe workplace.

From Chapter 1 of *Principles of Electric Circuits: Conventional Current Version*, Ninth Edition, Thomas L. Floyd.

1 Units of Measurement

In the 19th century, the principal weight and measurement units dealt with commerce. As technology advanced, scientists and engineers saw the need for international standard measurement units. In 1875, at a conference called by the French, representatives from eighteen nations signed a treaty that established international standards. Today, all engineering and scientific work use an improved international system of units, Le Système International d'Unités, abbreviated **SI***.

After completing this section, you should be able to

- **Discuss the SI standard**
  - Specify the fundamental SI units
  - Specify the supplementary units
  - Explain what derived units are

Fundamental and Derived Units

The SI system is based on seven fundamental units (sometimes called *base units*) and two supplementary units. All measurements can be expressed as some combination of fundamental and supplementary units. Table 1 lists the fundamental units, and Table 2 lists the supplementary units.

The fundamental electrical unit, the ampere, is the unit for electrical current. Current is abbreviated with the letter I (for intensity) and uses the symbol A (for ampere). The ampere is unique in that it uses the fundamental unit of time (t) in its definition (second). All other electrical and magnetic units (such as voltage, power, and magnetic flux) use various combinations of fundamental units in their definitions and are called *derived units*.

For example, the derived unit of voltage, which is the volt (V), is defined in terms of fundamental units as $\text{m}^2 \cdot \text{kg} \cdot \text{s}^{-3} \cdot \text{A}^{-1}$. As you can see, this combination of fundamental units is very cumbersome and impractical. Therefore, volt is used as the derived unit.

TABLE 1

SI fundamental units.

QUANTITY	UNIT	SYMBOL
Length	Meter	m
Mass	Kilogram	kg
Time	Second	s
Electric current	Ampere	A
Temperature	Kelvin	K
Luminous intensity	Candela	cd
Amount of substance	Mole	mol

TABLE 2

SI supplementary units.

QUANTITY	UNIT	SYMBOL
Plane angle	Radian	r
Solid angle	Steradian	sr

This icon indicates selected websites for further information on topics in this section. See the Companion Website provided with this text.

***The bold terms in color are key terms and are defined at the end of the chapter.**

Letter symbols are used to represent both quantities and their units. One symbol is used to represent the name of the quantity, and another symbol is used to represent the unit of measurement of that quantity. For example, italic P stands for *power,* and nonitalic W stands for *watt,* which is the unit of power. Another example is voltage, where the same letter stands for both the quantity and its unit. Italic V represents voltage and nonitalic V represents *volt*, which is the unit of voltage. As a rule, italic letters stand for the quantity and nonitalic (roman) letters represent the unit of that quantity.

Table 3 lists the most important electrical quantities, along with their derived SI units and symbols. Table 4 lists magnetic quantities, along with their derived SI units and symbols.

◀ TABLE 3

Electrical quantities and derived units with SI symbols.

QUANTITY	SYMBOL	SI UNIT	SYMBOL
Capacitance	C	Farad	F
Charge	Q	Coulomb	C
Conductance	G	Siemens	S
Energy (work)	W	Joule	J
Frequency	f	Hertz	Hz
Impedance	Z	Ohm	Ω
Inductance	L	Henry	H
Power	P	Watt	W
Reactance	X	Ohm	Ω
Resistance	R	Ohm	Ω
Voltage	V	Volt	V

◀ TABLE 4

Magnetic quantities and derived units with SI symbols.

QUANTITY	SYMBOL	SI UNIT	SYMBOL
Magnetic field intensity	H	Ampere-turns/meter	At/m
Magnetic flux	ϕ	Weber	Wb
Magnetic flux density	B	Tesla	T
Magnetomotive force	F_m	Ampere-turn	At
Permeability	μ	Webers/ampere-turn · meter	Wb/At · m
Reluctance	$\mathscr{R}$	Ampere-turns/weber	At/Wb

In addition to the common electrical units shown in Table 3, the SI system has many other units that are defined in terms of certain fundamental units. In 1954, by international agreement, *meter, kilogram, second, ampere, degree Kelvin*, and *candela* were adopted as the basic SI units (*degree Kelvin* was later changed to just *kelvin*). These units form the basis of the mks (for meter-kilogram-second) units that are used for derived quantities and have become the preferred units for nearly all scientific and engineering work. An older metric system, called the cgs system, was based on the centimeter, gram, and second as fundamental units. There are still a number of units in common use based on the cgs system; for example, the gauss is a magnetic flux unit in the cgs system and is still in common usage. In keeping with preferred practice, we use mks units, except when otherwise noted.

SECTION 1 CHECKUP
Answers are at the end of the chapter.

1. How does a fundamental unit differ from a derived unit?
2. What is the fundamental electrical unit?
3. What does *SI* stand for?
4. Without referring to Table 3, list as many electrical quantities as possible, including their symbols, units, and unit symbols.
5. Without referring to Table 4, list as many magnetic quantities as possible, including their symbols, units, and unit symbols.

2 SCIENTIFIC NOTATION

In electrical and electronics fields, both very small and very large quantities are commonly used. For example, it is common to have electrical current values of only a few thousandths or even a few millionths of an ampere and to have resistance values ranging up to several thousand or several million ohms.

After completing this section, you should be able to

- **Use scientific notation (powers of ten) to represent quantities**
  - Express any number using a power of ten
  - Perform calculations with powers of ten

Scientific notation provides a convenient method to represent large and small numbers and to perform calculations involving such numbers. In scientific notation, a quantity is expressed as a product of a number between 1 and 10 and a power of ten. For example, the quantity 150,000 is expressed in scientific notation as 1.5×10^5, and the quantity 0.00022 is expressed as 2.2×10^{-4}.

Powers of Ten

Table 5 lists some powers of ten, both positive and negative, and the corresponding decimal numbers. The **power of ten** is expressed as an exponent of the base 10 in each case (10^x). An **exponent** is a number to which a base number is raised. It indicates the number

TABLE 5

Some positive and negative powers of ten.

$10^6 = 1{,}000{,}000$	$10^{-6} = 0.000001$
$10^5 = 100{,}000$	$10^{-5} = 0.00001$
$10^4 = 10{,}000$	$10^{-4} = 0.0001$
$10^3 = 1{,}000$	$10^{-3} = 0.001$
$10^2 = 100$	$10^{-2} = 0.01$
$10^1 = 10$	$10^{-1} = 0.1$
$10^0 = 1$	

of places that the decimal point is moved to the right or left to produce the decimal number. For a positive power of ten, move the decimal point to the right to get the equivalent decimal number. For example, for an exponent of 4,

$$10^4 = 1 \times 10^4 = 1\underset{\curvearrowright}{.0000.} = 10{,}000$$

For a negative the power of ten, move the decimal point to the left to get the equivalent decimal number. For example, for an exponent of −4,

$$10^{-4} = 1 \times 10^{-4} = \underset{\curvearrowleft}{.0001.} = 0.0001$$

EXAMPLE 1

Express each number in scientific notation.

(a) 200 **(b)** 5000 **(c)** 85,000 **(d)** 3,000,000

Solution In each case, move the decimal point an appropriate number of places to the left to determine the positive power of ten. Notice that the result is always a number between 1 and 10 times a power of ten.

(a) $200 = \mathbf{2 \times 10^2}$ **(b)** $5000 = \mathbf{5 \times 10^3}$

(c) $85{,}000 = \mathbf{8.5 \times 10^4}$ **(d)** $3{,}000{,}000 = \mathbf{3 \times 10^6}$

*Related Problem** Express 4750 in scientific notation.

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*Answers are at the end of the chapter.

EXAMPLE 2

Express each number in scientific notation.

(a) 0.2 **(b)** 0.005 **(c)** 0.00063 **(d)** 0.000015

Solution In each case, move the decimal point an appropriate number of places to the right to determine the negative power of ten.

(a) $0.2 = \mathbf{2 \times 10^{-1}}$ **(b)** $0.005 = \mathbf{5 \times 10^{-3}}$

(c) $0.00063 = \mathbf{6.3 \times 10^{-4}}$ **(d)** $0.000015 = \mathbf{1.5 \times 10^{-5}}$

Related Problem Express 0.00738 in scientific notation.

EXAMPLE 3

Express each of the following as a regular decimal number:

(a) 1×10^5 **(b)** 2×10^3 **(c)** 3.2×10^{-2} **(d)** 2.50×10^{-6}

Solution Move the decimal point to the right or left a number of places indicated by the positive or the negative power of ten respectively.

(a) $1 \times 10^5 = \mathbf{100{,}000}$ **(b)** $2 \times 10^3 = \mathbf{2000}$

(c) $3.2 \times 10^{-2} = \mathbf{0.032}$ **(d)** $2.5 \times 10^{-6} = \mathbf{0.0000025}$

Related Problem Express 9.12×10^3 as a regular decimal number.