QUANTITIES AND UNITS 1

CHAPTER OUTLINE

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

KEY TERMS

- SI
- Scientific notation
- Power of ten
- Exponent
- Engineering notation
- Metric prefix

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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 throughout the book remind you of the importance of safety and provide tips for a safe workplace. Basic safety precautions are introduced in Chapter 2.

1–1 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 1–1 lists the fundamental units, and Table 1–2 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 $m^2 \cdot kg \cdot s^{-3} \cdot A^{-1}$. As you can see, this combination of fundamental units is very cumbersome and impractical. Therefore, volt is used as the derived unit.

▶ TABLE 1–1
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 1–2
SI supplementary units.

QUANTITY	UNIT	SYMBOL
Plane angle	Radian	r
Solid angle	Steradian	sr

***All bold terms are in the end-of-book glossary. The bold terms in color are key terms and are also 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, *P* stands for *power,* and W stands for *watt,* which is the unit of power. Another example is voltage. In this case, the same letter stands for both the quantity and its unit. Italic *V* represents voltage and nonitalic V represents the volt, which is the unit of voltage. As a rule, italic letters stand for the quantity and nonitalic letters represent the unit of that quantity.

Table 1–3 lists the most important electrical quantities, along with their derived SI units and symbols. Table 1–4 lists magnetic quantities, along with their derived SI units and symbols.

TABLE 1–3

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	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 1–4

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	$\mathfrak{R}$	Ampere-turns/weber	At/Wb

SECTION 1–1 REVIEW
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 1–3, list as many electrical quantities as possible, including their symbols, units, and unit symbols.
5. Without referring to Table 1–4, list as many magnetic quantities as possible, including their symbols, units, and unit symbols.

1–2 SCIENTIFIC NOTATION

In electrical and electronics fields, you will encounter both very small and very large quantities. 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 1–5 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 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,

$$10^4 = 1 \times 10^4 = 1.0000. = 10{,}000$$

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,

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

▼ **TABLE 1–5**

Some positive and negative powers of ten.

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

EXAMPLE 1–1

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.

(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.

*Answers are at the end of the chapter.

EXAMPLE 1–2

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 1–3

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.

Calculations Using Powers of Ten

The advantage of scientific notation is in addition, subtraction, multiplication, and division of very small or very large numbers.

Addition The steps for adding numbers in powers of ten are as follows:

1. Express the numbers to be added in the same power of ten.
2. Add the numbers without their powers of ten to get the sum.
3. Bring down the common power of ten, which is the power of ten of the sum.

EXAMPLE 1–4

Add 2×10^6 and 5×10^7 and express the result in scientific notation.

Solution

1. Express both numbers in the same power of ten: $(2 \times 10^6) + (50 \times 10^6)$.
2. Add $2 + 50 = 52$.
3. Bring down the common power of ten (10^6); the sum is $52 \times 10^6 = \mathbf{5.2 \times 10^7}$.

Related Problem Add 3.1×10^3 and 5.5×10^4.

Subtraction The steps for subtracting numbers in powers of ten are as follows:

1. Express the numbers to be subtracted in the same power of ten.
2. Subtract the numbers without their powers of ten to get the difference.
3. Bring down the common power of ten, which is the power of ten of the difference.

EXAMPLE 1–5

Subtract 2.5×10^{-12} from 7.5×10^{-11} and express the result in scientific notation.

Solution

1. Express each number in the same power of ten: $(7.5 \times 10^{-11}) - (0.25 \times 10^{-11})$.
2. Subtract $7.5 - 0.25 = 7.25$.
3. Bring down the common power of ten (10^{-11}); the difference is $\mathbf{7.25 \times 10^{-11}}$.

Related Problem Subtract 3.5×10^{-6} from 2.2×10^{-5}.

Multiplication The steps for multiplying numbers in powers of ten are as follows:

1. Multiply the numbers directly without their powers of ten.
2. Add the powers of ten algebraically (the exponents do not have to be the same).

EXAMPLE 1–6

Multiply 5×10^{12} and 3×10^{-6} and express the result in scientific notation.

Solution Multiply the numbers, and algebraically add the powers.

$$(5 \times 10^{12})(3 \times 10^{-6}) = 15 \times 10^{12+(-6)} = 15 \times 10^6 = \mathbf{1.5 \times 10^7}$$

Related Problem Multiply 3.2×10^6 and 1.5×10^{-3}.

Division The steps for dividing numbers in powers of ten are as follows:

1. Divide the numbers directly without their powers of ten.
2. Subtract the power of ten in the denominator from the power of ten in the numerator (the powers do not have to be the same).

EXAMPLE 1–7 Divide 5.0×10^8 by 2.5×10^3 and express the result in scientific notation.

Solution Write the division problem with a numerator and denominator as

$$\frac{5.0 \times 10^8}{2.5 \times 10^3}$$

Divide the numbers and subtract the powers of ten (3 from 8).

$$\frac{5.0 \times 10^8}{2.5 \times 10^3} = 2 \times 10^{8-3} = \mathbf{2 \times 10^5}$$

Related Problem Divide 8×10^{-6} by 2×10^{-10}.

SECTION 1–2 REVIEW

1. Scientific notation uses powers of ten. (True or False)
2. Express 100 as a power of ten.
3. Express the following numbers in scientific notation:
   (a) 4350 (b) 12,010 (c) 29,000,000
4. Express the following numbers in scientific notation:
   (a) 0.760 (b) 0.00025 (c) 0.000000597
5. Do the following operations:
   (a) $(1 \times 10^5) + (2 \times 10^5)$ (b) $(3 \times 10^6)(2 \times 10^4)$
   (c) $(8 \times 10^3) \div (4 \times 10^2)$ (d) $(2.5 \times 10^{-6}) - (1.3 \times 10^{-7})$

1–3 ENGINEERING NOTATION AND METRIC PREFIXES

Engineering notation, a specialized form of scientific notation, is used widely in technical fields to represent large and small quantities. In electronics, engineering notation is used to represent values of voltage, current, power, resistance, capacitance, inductance, and time, to name a few. Metric prefixes are used in conjunction with engineering notation as a "short hand" for the certain powers of ten that are multiples of three.

After completing this section, you should be able to

- **Use engineering notation and metric prefixes to represent large and small quantities**
  - List the metric prefixes
  - Change a power of ten in engineering notation to a metric prefix
  - Use metric prefixes to express electrical quantities
  - Convert one metric prefix to another

Engineering Notation

Engineering notation is similar to scientific notation. However, in **engineering notation** a number can have from one to three digits to the left of the decimal point and the power-of-ten exponent must be a multiple of three. For example, the number 33,000 expressed in engineering notation is 33×10^3. In scientific notation, it is expressed as 3.3×10^4. As another example, the number 0.045 expressed in engineering notation is 45×10^{-3}. In scientific notation, it is expressed as 4.5×10^{-2}.

EXAMPLE 1–8 Express the following numbers in engineering notation:

(a) 82,000 **(b)** 243,000 **(c)** 1,956,000

Solution In engineering notation,

(a) 82,000 is expressed as $\mathbf{82 \times 10^3}$.

(b) 243,000 is expressed as $\mathbf{243 \times 10^3}$.

(c) 1,956,000 is expressed as $\mathbf{1.956 \times 10^6}$.

Related Problem Express 36,000,000,000 in engineering notation.

EXAMPLE 1–9 Convert each of the following numbers to engineering notation:

(a) 0.0022 **(b)** 0.000000047 **(c)** 0.00033

Solution In engineering notation,

(a) 0.0022 is expressed as $\mathbf{2.2 \times 10^{-3}}$.

(b) 0.000000047 is expressed as $\mathbf{47 \times 10^{-9}}$.

(c) 0.00033 is expressed as $\mathbf{330 \times 10^{-6}}$.

Related Problem Express 0.0000000000056 in engineering notation.

Metric Prefixes

In engineering notation **metric prefixes** represent each of the most commonly used powers of ten. These metric prefixes are listed in Table 1–6 with their symbols and corresponding powers of ten.

Metric prefixes are used only with numbers that have a unit of measure, such as volts, amperes, and ohms, and precede the unit symbol. For example, 0.025 amperes can be expressed in engineering notation as 25×10^{-3} A. This quantity expressed using a metric prefix is 25 mA, which is read 25 milliamps. Note that the metric prefix *milli* has replaced 10^{-3}.

TABLE 1–6

Metric prefixes with their symbols and corresponding powers of ten and values.

METRIC PREFIX	SYMBOL	POWER OF TEN	VALUE
femto	f	10^{-15}	one-quadrillionth
pico	p	10^{-12}	one-trillionth
nano	n	10^{-9}	one-billionth
micro	μ	10^{-6}	one-millionth
milli	m	10^{-3}	one-thousandth
kilo	k	10^{3}	one thousand
mega	M	10^{6}	one million
giga	G	10^{9}	one billion
tera	T	10^{12}	one trillion

As another example, 100,000,000 ohms can be expressed as $100 \times 10^6\ \Omega$. This quantity expressed using a metric prefix is 100 MΩ, which is read 100 megohms. The metric prefix *mega* has replaced 10^6.

EXAMPLE 1–10 Express each quantity using a metric prefix:

(a) 50,000 V (b) 25,000,000 Ω (c) 0.000036 A

Solution

(a) $50{,}000\ \text{V} = 50 \times 10^3\ \text{V} = \mathbf{50\ kV}$

(b) $25{,}000{,}000\ \Omega = 25 \times 10^6\ \Omega = \mathbf{25\ M\Omega}$

(c) $0.000036\ \text{A} = 36 \times 10^{-6}\ \text{A} = \mathbf{36\ \mu A}$

Related Problem Express using metric prefixes:

(a) 56,000,000 Ω (b) 0.000470 A

Calculator Tip

All scientific and graphing calculators provide features for entering and displaying numbers in various formats. Scientific and engineering notation are special cases of exponential (power of ten) notation. Most calculators have a key labeled EE (or EXP) that is used to enter the exponent of numbers. To enter a number in exponential notation, enter the base number first, including the sign, and then press the EE key, followed by the exponent, including the sign.

Scientific and graphing calculators have displays for showing the power of ten. Some calculators display the exponent as a small raised number on the right side of the display.

47.0 ⁰³

Other calculators display the number with a small E followed by the exponent.

47.0E03

Notice that the base 10 is not generally shown, but it is implied or represented by the E. When you write the number out, you need to include the base 10. The displayed number shown above is written out as 47.0×10^3.

Some calculators are placed in the scientific or engineering notation mode using a secondary or tertiary function, such as SCI or ENG. Then numbers are entered in regular decimal form. The calculator automatically converts them to the proper format. Other calculators provide for mode selection using a menu.

Always check the owner's manual for your particular calculator to determine how to use the exponential notation features.

SECTION 1–3 REVIEW

1. Express the following numbers in engineering notation:
   (a) 0.0056 (b) 0.0000000283 (c) 950,000 (d) 375,000,000,000
2. List the metric prefix for each of the following powers of ten:
   10^6, 10^3, 10^{-3}, 10^{-6}, 10^{-9}, and 10^{-12}
3. Use an appropriate metric prefix to express 0.000001 A.
4. Use an appropriate metric prefix to express 250,000 W.

1–4 METRIC UNIT CONVERSIONS

It is sometimes necessary or convenient to convert a quantity from one unit with a metric prefix to another, such as from milliamperes (mA) to microamperes (μA). Moving the decimal point in the number an appropriate number of places to the left or to the right, depending on the particular conversion, results in a metric unit conversion.

After completing this section, you should be able to

- **Convert from one unit with a metric prefix to another**
  - Convert between milli, micro, nano, and pico
  - Convert between kilo and mega

The following basic rules apply to metric unit conversions:

1. When converting from a larger unit to a smaller unit, move the decimal point to the right.
2. When converting from a smaller unit to a larger unit, move the decimal point to the left.
3. Determine the number of places to move the decimal point by finding the difference in the powers of ten of the units being converted.

For example, when converting from milliamperes (mA) to microamperes (μA), move the decimal point three places to the right because there is a three-place difference between the two units (mA is 10^{-3} A and μA is 10^{-6} A). The following examples illustrate a few conversions.

EXAMPLE 1–11 Convert 0.15 milliampere (0.15 mA) to microamperes (μA).

Solution Move the decimal point three places to the right.

$$0.15\text{ mA} = 0.15 \times 10^{-3}\text{ A} = 150 \times 10^{-6}\text{ A} = \mathbf{150\ \mu A}$$

Related Problem Convert 1 mA to microamperes.

EXAMPLE 1–12 Convert 4500 microvolts (4500 μV) to millivolts (mV).

Solution Move the decimal point three places to the left.

$$4500\ \mu\text{V} = 4500 \times 10^{-6}\text{ V} = 4.5 \times 10^{-3}\text{ V} = \mathbf{4.5\ mV}$$

Related Problem Convert 1000 μV to millivolts.

EXAMPLE 1–13 Convert 5000 nanoamperes (5000 nA) to microamperes (μA).

Solution Move the decimal point three places to the left.

$$5000\text{ nA} = 5000 \times 10^{-9}\text{ A} = 5 \times 10^{-6}\text{ A} = \mathbf{5\ \mu A}$$

Related Problem Convert 893 nA to microamperes.

EXAMPLE 1–14 Convert 47,000 picofarads (47,000 pF) to microfarads (μF).

Solution Move the decimal point six places to the left.

$$47{,}000\,\text{pF} = 47{,}000 \times 10^{-12}\,\text{F} = 0.047 \times 10^{-6}\,\text{F} = \mathbf{0.047\,\mu F}$$

Related Problem Convert 10,000 pF to microfarads.

EXAMPLE 1–15 Convert 0.00022 microfarad (0.00022 μF) to picofarads (pF).

Solution Move the decimal point six places to the right.

$$0.00022\,\mu\text{F} = 0.00022 \times 10^{-6}\,\text{F} = 220 \times 10^{-12}\,\text{F} = \mathbf{220\,pF}$$

Related Problem Convert 0.0022 μF to picofarads.

EXAMPLE 1–16 Convert 1800 kilohms (1800 kΩ) to megohms (MΩ).

Solution Move the decimal point three places to the left.

$$1800\,\text{k}\Omega = 1800 \times 10^{3}\,\Omega = 1.8 \times 10^{6}\,\Omega = \mathbf{1.8\,M\Omega}$$

Related Problem Convert 2.2 kΩ to megohms.

When adding (or subtracting) quantities with different metric prefixes, first convert one of the quantities to the same prefix as the other quantity.

EXAMPLE 1–17 Add 15 mA and 8000 μA and express the sum in milliamperes.

Solution Convert 8000 μA to 8 mA and add.

$$\begin{aligned}15\,\text{mA} + 8000\,\mu\text{A} &= 15 \times 10^{-3}\,\text{A} + 8000 \times 10^{-6}\,\text{A}\\ &= 15 \times 10^{-3}\,\text{A} + 8 \times 10^{-3}\,\text{A} = 15\,\text{mA} + 8\,\text{mA} = \mathbf{23\,mA}\end{aligned}$$

Related Problem Add 2873 mA to 10,000 μA; express the sum in milliamperes.

SECTION 1–4 REVIEW

1. Convert 0.01 MV to kilovolts (kV).
2. Convert 250,000 pA to milliamperes (mA).
3. Add 0.05 MW and 75 kW and express the result in kW.
4. Add 50 mV and 25,000 μV and express the result in mV.

SUMMARY

- SI is an abbreviation for Le Système International d'Unités and is a standardized system of units.
- A fundamental unit is an SI unit from which other SI units are derived. There are seven fundamental units.
- Scientific notation is a method for representing very large and very small numbers as a number between one and ten (one digit to left of decimal point) times a power of ten.
- Engineering notation is a form of scientific notation in which quantities are represented with one, two, or three digits to the left of the decimal point times a power of ten that is a multiple of three.
- Metric prefixes represent powers of ten in numbers expressed in engineering notation.

KEY TERMS

These key terms are also defined in the end-of-book glossary.

Engineering notation A system for representing any number as a one-, two-, or three-digit number times a power of ten with an exponent that is a multiple of 3.

Exponent The number to which a base number is raised.

Metric prefix An affix that represents a power-of-ten number expressed in engineering notation.

Power of ten A numerical representation consisting of a base of 10 and an exponent; the number 10 raised to a power.

Scientific notation A system for representing any number as a number between 1 and 10 times an appropriate power of ten.

SI Standardized internationalized system of units used for all engineering and scientific work; abbreviation for French *Le Système International d'Unités*.

SELF-TEST

Answers are at the end of the chapter.

1. Which of the following is not an electrical quantity?
  (a) current **(b)** voltage **(c)** time **(d)** power

2. The unit of current is
  (a) volt **(b)** watt **(c)** ampere **(d)** joule

3. The unit of voltage is
  (a) ohm **(b)** watt **(c)** volt **(d)** farad

4. The unit of resistance is
  (a) ampere **(b)** henry **(c)** hertz **(d)** ohm

5. Hertz is the unit of
  (a) power **(b)** inductance **(c)** frequency **(d)** time

6. 15,000 W is the same as
  (a) 15 mW **(b)** 15 kW **(c)** 15 MW **(d)** 15 μW

7. The quantity 4.7×10^3 is the same as
  (a) 470 **(b)** 4700 **(c)** 47,000 **(d)** 0.0047

8. The quantity 56×10^{-3} is the same as
  (a) 0.056 **(b)** 0.560 **(c)** 560 **(d)** 56,000

9. The number 3,300,000 can be expressed in engineering notation as
  (a) 3300×10^3 **(b)** 3.3×10^{-6} **(c)** 3.3×10^6 **(d)** either answer (a) or (c)

10. Ten milliamperes can be expressed as
  (a) 10 MA **(b)** 10 μA **(c)** 10 kA **(d)** 10 mA

11. Five thousand volts can be expressed as
  (a) 5000 V **(b)** 5 MV **(c)** 5 kV **(d)** either answer (a) or (c)

12. Twenty million ohms can be expressed as
  (a) 20 mΩ **(b)** 20 MW **(c)** 20 MΩ **(d)** 20 $\mu\Omega$

PROBLEMS

Answers to odd-numbered problems are at the end of the book.

SECTION 1–2 Scientific Notation

1. Express each of the following numbers in scientific notation:
   (a) 3000 (b) 75,000 (c) 2,000,000
2. Express each fractional number in scientific notation:
   (a) 1/500 (b) 1/2000 (c) 1/5,000,000
3. Express each of the following numbers in scientific notation:
   (a) 8400 (b) 99,000 (c) 0.2×10^6
4. Express each of the following numbers in scientific notation:
   (a) 0.0002 (b) 0.6 (c) 7.8×10^{-2}
5. Express each of the following numbers in scientific notation:
   (a) 32×10^3 (b) 6800×10^{-6} (c) 870×10^8
6. Express each of the following as a regular decimal number:
   (a) 2×10^5 (b) 5.4×10^{-9} (c) 1.0×10^1
7. Express each of the following as a regular decimal number:
   (a) 2.5×10^{-6} (b) 5.0×10^2 (c) 3.9×10^{-1}
8. Express each number in regular decimal form:
   (a) 4.5×10^{-6} (b) 8×10^{-9} (c) 4.0×10^{-12}
9. Add the following numbers:
   (a) $(9.2 \times 10^6) + (3.4 \times 10^7)$ (b) $(5 \times 10^3) + (8.5 \times 10^{-1})$
   (c) $(5.6 \times 10^{-8}) + (4.6 \times 10^{-9})$
10. Perform the following subtractions:
    (a) $(3.2 \times 10^{12}) - (1.1 \times 10^{12})$ (b) $(2.6 \times 10^8) - (1.3 \times 10^7)$
    (c) $(1.5 \times 10^{-12}) - (8 \times 10^{-13})$
11. Perform the following multiplications:
    (a) $(5 \times 10^3)(4 \times 10^5)$ (b) $(1.2 \times 10^{12})(3 \times 10^2)$
    (c) $(2.2 \times 10^{-9})(7 \times 10^{-6})$
12. Divide the following:
    (a) $(1.0 \times 10^3) \div (2.5 \times 10^2)$ (b) $(2.5 \times 10^{-6}) \div (5.0 \times 10^{-8})$
    (c) $(4.2 \times 10^8) \div (2 \times 10^{-5})$

SECTION 1–3 Engineering Notation and Metric Prefixes

13. Express each of the following numbers in engineering notation:
    (a) 89,000 (b) 450,000 (c) 12,040,000,000,000
14. Express each number in engineering notation:
    (a) 2.35×10^5 (b) 7.32×10^7 (c) 1.333×10^9
15. Express each number in engineering notation:
    (a) 0.000345 (b) 0.025 (c) 0.00000000129
16. Express each number in engineering notation:
    (a) 9.81×10^{-3} (b) 4.82×10^{-4} (c) 4.38×10^{-7}
17. Add the following numbers and express each result in engineering notation:
    (a) $(2.5 \times 10^{-3}) + (4.6 \times 10^{-3})$ (b) $(68 \times 10^6) + (33 \times 10^6)$
    (c) $(1.25 \times 10^6) + (250 \times 10^3)$
18. Multiply the following numbers and express each result in engineering notation:
    (a) $(32 \times 10^{-3})(56 \times 10^3)$ (b) $(1.2 \times 10^{-6})(1.2 \times 10^{-6})$
    (c) $100(55 \times 10^{-3})$

19. Divide the following numbers and express each result in engineering notation:
(a) $50 \div (2.2 \times 10^3)$ (b) $(5 \times 10^3) \div (25 \times 10^{-6})$
(c) $560 \times 10^3 \div (660 \times 10^3)$
20. Express each number in Problem 13 in ohms using a metric prefix.
21. Express each number in Problem 15 in amperes using a metric prefix.
22. Express each of the following as a quantity having a metric prefix:
(a) 31×10^{-3} A (b) 5.5×10^3 V (c) 20×10^{-12} F
23. Express the following using metric prefixes:
(a) 3×10^{-6} F (b) $3.3 \times 10^6\ \Omega$ (c) 350×10^{-9} A
24. Express the following using metric prefixes:
(a) 2.5×10^{-12} A (b) 8×10^9 Hz (c) $4.7 \times 10^3\ \Omega$
25. Express each quantity by converting the metric prefix to a power-of-10:
(a) 7.5 pA (b) 3.3 GHz (c) 280 nW
26. Express each quantity in engineering notation:
(a) 5 μA (b) 43 mV (c) 275 kΩ (d) 10 MW

SECTION 1–4 Metric Unit Conversions

27. Perform the indicated conversions:
(a) 5 mA to microamperes (b) 3200 μW to milliwatts
(c) 5000 kV to megavolts (d) 10 MW to kilowatts
28. Determine the following:
(a) The number of microamperes in 1 milliampere
(b) The number of millivolts in 0.05 kilovolt
(c) The number of megohms in 0.02 kilohm
(d) The number of kilowatts in 155 milliwatts
29. Add the following quantities:
(a) 50 mA + 680 μA (b) 120 kΩ + 2.2 MΩ (c) 0.02 μF + 3300 pF
30. Do the following operations:
(a) 10 kΩ ÷ (2.2 kΩ + 10 kΩ) (b) 250 mV ÷ 50 μV (c) 1 MW ÷ 2 kW

ANSWERS

SECTION REVIEWS

SECTION 1–1 Units of Measurement

1. Fundamental units define derived units.
2. Ampere
3. SI is the abbreviation for Système International.
4. Refer to Table 1–3 after you have compiled your list of electrical quantities.
5. Refer to Table 1–4 after you have compiled your list of magnetic quantities.

SECTION 1–2 Scientific Notation

1. True
2. 10^2
3. (a) 4.35×10^3 (b) 1.201×10^4 (c) 2.9×10^7
4. (a) 7.6×10^{-1} (b) 2.5×10^{-4} (c) 5.97×10^{-7}
5. (a) 3×10^5 (b) 6×10^{10} (c) 2×10^1 (d) 2.37×10^{-6}

SECTION 1–3 Engineering Notation and Metric Prefixes

1. **(a)** 5.6×10^{-3} **(b)** 28.3×10^{-9} **(c)** 950×10^{3} **(d)** 375×10^{9}
2. Mega (M), kilo (k), milli (m), micro (μ), nano (n), and pico (p)
3. 1 μA (one microampere)
4. 250 kW (250 kilowatts)

SECTION 1–4 Metric Unit Conversions

1. 0.01 MV = 10 kV
2. 250,000 pA = 0.00025 mA
3. 0.05 MW + 75 kW = 50 kW + 75 kW = 125 kW
4. 50 mV + 25,000 μV = 50 mV + 25 mV = 75 mV

RELATED PROBLEMS FOR EXAMPLES

1–1 4.75×10^{3}
1–2 7.38×10^{-3}
1–3 9120
1–4 5.81×10^{4}
1–5 1.85×10^{-5}
1–6 4.8×10^{3}
1–7 4×10^{4}
1–8 36×10^{9}
1–9 5.6×10^{-12}
1–10 **(a)** 56 MΩ **(b)** 470 μA
1–11 1000 μA
1–12 1 mV
1–13 0.893 μA
1–14 0.01 μF
1–15 2200 pF
1–16 0.0022 MΩ
1–17 2883 mA

SELF-TEST

1. (c) **2.** (c) **3.** (c) **4.** (d) **5.** (c) **6.** (b)
7. (b) **8.** (a) **9.** (d) **10.** (d) **11.** (d) **12.** (c)