Chapter 1: Circuit Variables

1.1 Electrical Engineering: An Overview

5 Major Classifications of Electrical Engineering

- *i. Communication Systems:* electrical systems that generate, transmit, and distribute information (TV, radio, radar, etc.)
- *ii. Computer Systems:* use electrical signals to process information (Calculator, PC, networks, etc.)
- *iii. Control Systems:* use electrical signals to regulate processes (HVAC, autopilot, etc.)
- *iv. Power Systems:* generate and distribute power (nuclear, thermal, etc.)
- *v. Signal-processing Systems:* act on electrical signal that represent information (CT scans, etc.)

<u>Circuit Theory</u>

A special case of electromagnetic field theory; the study of static and moving electric charges

Electric Circuit: a mathematical model that approximates the behavior of an actual electrical system.

Three assumptions that permit circuit theory, rather than electromagnetic field theory, to be used to study a physical system as an electrical circuit:

1. *Electrical effects happen instantaneously throughout the system.* The system is called a **lumped-parameter system.**
2. *The net charge on every component is always zero.*
3. *There is no magnetic coupling between the components in a system.*

Problem Solving

General steps to problem solving

a. Identify what is given (known) and what needs to be found (unknowns)
b. Sketch a circuit diagram or other visual aid
c. Think of several methods for determining the solution and a method for choosing between them
d. Calculate a solution
e. Be creative
f. Test the validity of your solution

1.2 The International System of Units

TABLE 1.1 The International System of Units (SI)

Quantity	Basic Unit	Symbol
Length	meter	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	degree kelvin	K
Amount of substance	mole	mol
Luminous intensity	candela	cd

TABLE 1.2 Derived Units in SI

Quantity	Unit Name (Symbol)	Formula
Frequency	hertz (Hz)	s^{-1}
Force	newton (N)	$kg \cdot m/s^2$
Energy or work	joule (J)	$N \cdot m$
Power	watt (W)	J/s
Electric charge	coulomb (C)	$A \cdot s$
Electric potential	volt (V)	J/C
Electric resistance	ohm (Ω)	V/A
Electric conductance	siemens (S)	A/V
Electric capacitance	farad (F)	C/V
Magnetic flux	weber (Wb)	$V \cdot s$
Inductance	henry (H)	Wb/A

TABLE 1.3 Standardized Prefixes to Signify Powers of 10

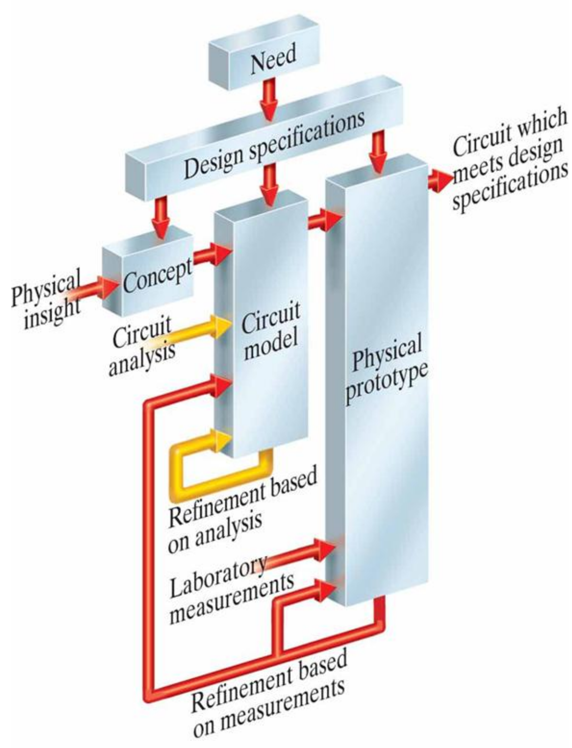
Prefix	Symbol	Power
atto	a	10^{-18}
femto	f	10^{-15}
pico	p	10^{-12}
nano	n	10^{-9}
micro	μ	10^{-6}
milli	m	10^{-3}
centi	c	10^{-2}
deci	d	10^{-1}
deka	da	10
hecto	h	10^{2}
kilo	k	10^{3}
mega	M	10^{6}
giga	G	10^{9}
tera	T	10^{12}

Review *Examples 1.1 and Assessment Problems 1.1 & 1.2*

1.3 Circuit Analysis: An Overview

Elements of circuit design

- There is a need
- Assessment results in a specification
- A concept for the design is developed
- The concept is translated to a mathematical model (circuit model)
    - The circuit model contains ideal circuit components which is a mathematical model of an actual electrical component
- Circuit analysis, mathematical techniques, is applied to the circuit model (If necessary the model is refined to improve the results)
- Once refined the circuit model is turned into a physical prototype



1.4 Voltage and Current

Characteristics of the electric charge

- The charge is bipolar; both positive and negative
- The electric charge exists in discrete quantities

- Electrical effects are attributed to both the separation of charge (voltage) and charges in motion (current)

Voltage: the energy per unit charge created by the separation of charges

$$v = \frac{dw}{dq};$$

v = voltage in volts; w = the energy in joules; q = the charge in coulombs

Current: the rate of charge flow

$$i = \frac{dq}{dt};$$

i = current in amperes; q = the charge in coulombs; t = the time in seconds

1.5 The Ideal Basic Circuit Element

Three attributes of an ideal basic circuit element

1. It has only 2 terminals; which are connection points to other circuit component
2. It is described mathematically in terms of current or voltage
3. It cannot be subdivided into other elements

Note: Ideal elements do not actually exist but are useful for modeling systems

For the following figure:

v = voltage; i = current; + and – are the polarity of the voltage → Indicates the direction of the current

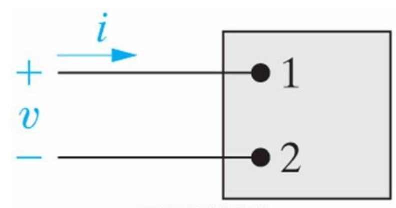


TABLE 1.4 Interpretation of Reference Directions in Fig. 1.5

	Positive Value	Negative Value
v	voltage drop from terminal 1 to terminal 2 *or* voltage rise from terminal 2 to terminal 1	voltage rise from terminal 1 to terminal 2 *or* voltage drop from terminal 2 to terminal 1
i	positive charge flowing from terminal 1 to terminal 2 *or* negative charge flowing from terminal 2 to terminal 1	positive charge flowing from terminal 2 to terminal 1 *or* negative charge flowing from terminal 1 to terminal 2

Generally the sign convention used for the referencing is:

Passive sign convention: whenever the reference direction for the current in an element is in the direction of the reference voltage drop across the element (like the figure), use positive sign in any expression that relates the voltage to the current. Otherwise, use a negative sign

Review Example 1.2 and Assessment Problems 1.3 & 1.4

1.6 Power and Energy

Power: the time rate of expanding or absorbing energy

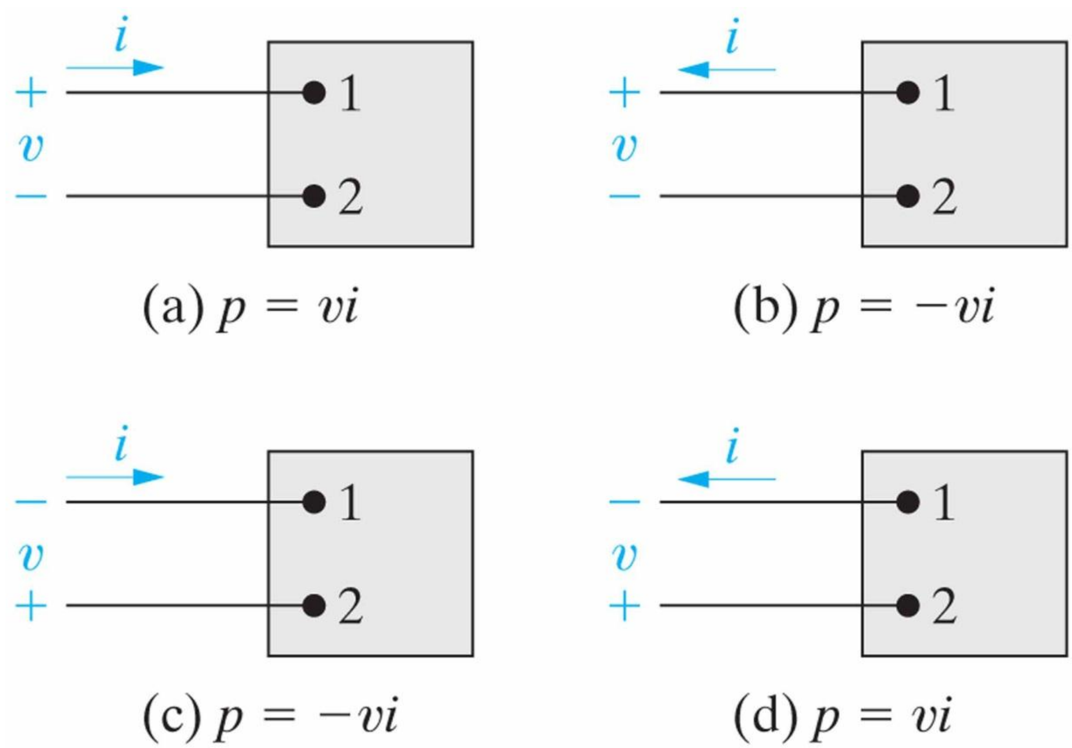
$$p = \frac{dw}{dt};$$

p = power in watts; w = the energy in joules; t = the time in seconds

Rewriting the equation,

$$p = \frac{dw}{dt} = \left(\frac{dw}{dq}\right)\left(\frac{dq}{dt}\right) = vi$$

Passive sign convention for power representation



Note: If the power is positive ($p > 0$), power is being **delivered to** the circuit inside the box. If the power is negative ($p < 0$), power is being **extracted from** the circuit inside the box.

Review Example 1.3 and Assessment Problems 1.5 - 1.7