Lecture 1

Introduction

Introduction

- Electric Circuit
- System of Units
- Charge
- Electric Current
- Voltage
- Power and Energy
- Circuit Elements

Electric Circuit

- An electric circuit is an interconnection of electrical elements.

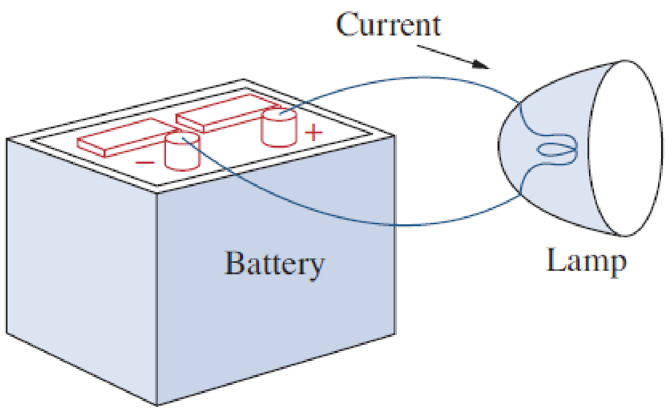


Figure 1.1
A simple electric circuit.

Electric Circuit

- An electric circuit is an interconnection of electrical elements.

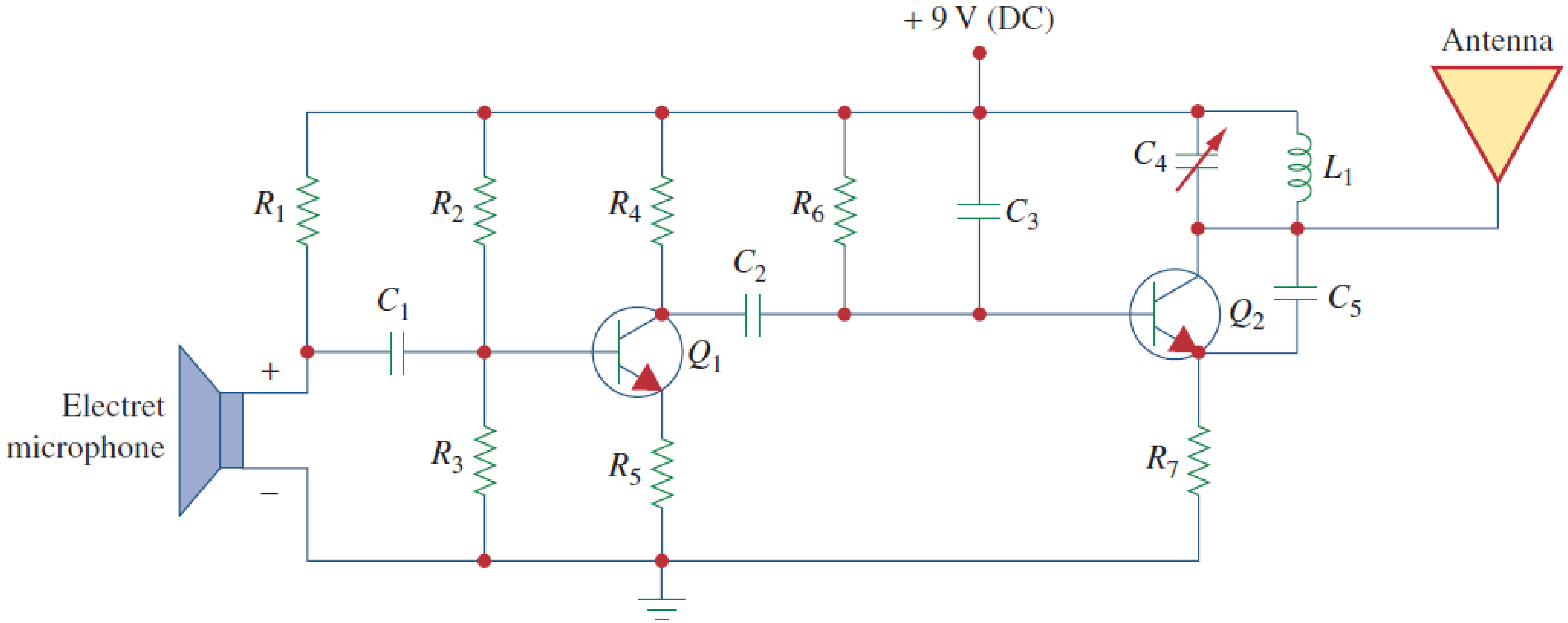


Figure 1.2
Electric circuit of a radio transmitter.

System of Units

- As electrical engineers, we deal with measurable quantities.
- An international measurement language is the International System of Units (SI)

TABLE 1.1

Six basic SI units and one derived unit relevant to this text.

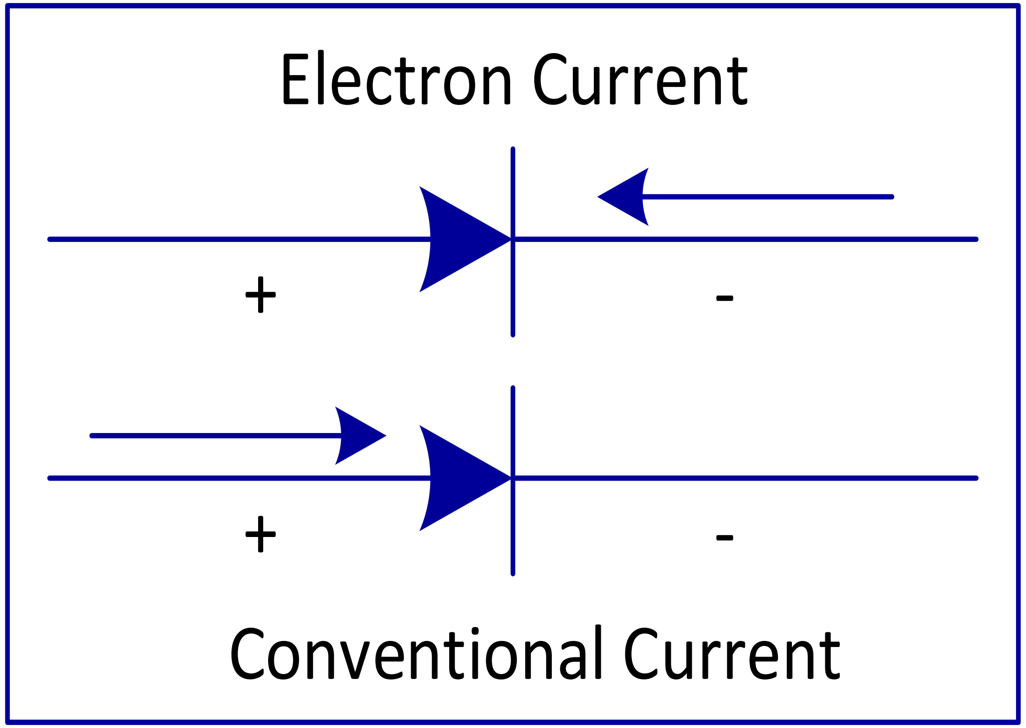
Quantity	Basic unit	Symbol
Length	meter	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Luminous intensity	candela	cd
Charge	coulomb	C

Charge

- Charge is an electrical property of the atomic particles of which matter consists, measured in coulombs (C).
- The coulomb is a large unit for charges. In 1 C of charge, there are electrons. Thus realistic or laboratory values of charges are on the order of pC, nC, or μC
- The *law of conservation of charge* states that charge can neither be created nor destroyed, only transferred.

Electric Current

- Current: The flow of electrons through a conductor
  - Measure in Ampere
  - Measured with Amp Meter
  - Electron Current flow
    - Negative to positive flow
  - Conventional Current flow
    - Positive to negative flow



Electric Current

- Electric current is the time rate of change of charge, measured in amperes (A).

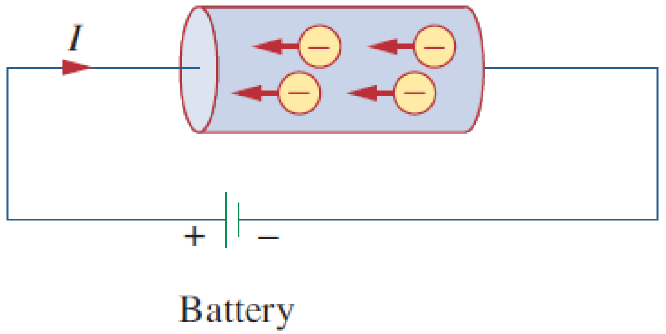


Figure 1.3
Electric current due to flow of electronic charge in a conductor.

Electric Current

- Electric current is the time rate of change of charge, measured in amperes (A).

$$i \triangleq \frac{dq}{dt}$$

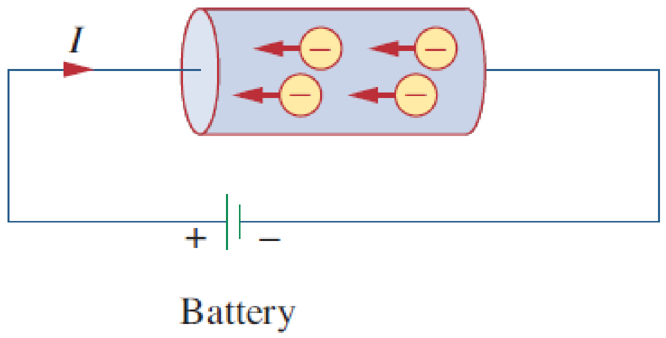


Figure 1.3
Electric current due to flow of electronic charge in a conductor.

- 1 ampere = 1 coulomb/second

Electric Current

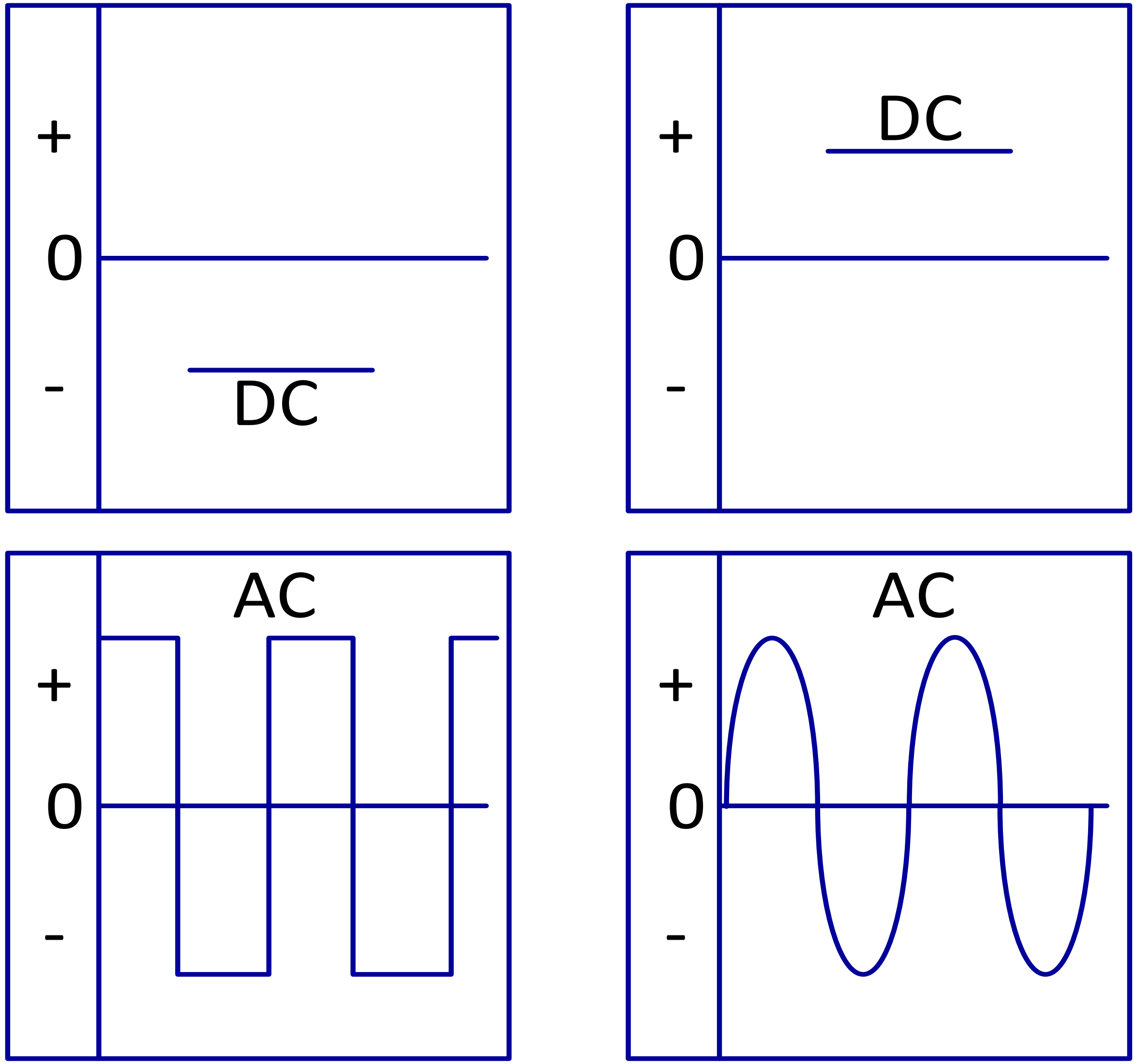
- The charge transferred between time and *t* is obtained by integrating both sides we obtain,

$$\boxed{Q \triangleq \int_{t_0}^{t} i\, dt}$$

Electric Current

- Direct Current-DC
  - ✓ Current flows in one direction only.
  - ✓ Car Battery
  - ✓ Photovoltaic cells
- Alternating Current-AC
  - ✓ Current flows in one direction, then the other, and alternates back and forth.
  - ✓ This is what is used in one’s home single phase.
  - ✓ Can be transformed

Electric Current



Electric Current

Example 1.2

The total charge entering a terminal is given by $q = 5t \sin 4\pi t$ mC. Calculate the current at $t = 0.5$ s.

Electric Current

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Solution:

$$i = \frac{dq}{dt} = \frac{d}{dt}(5t \sin 4\pi t) \text{ mC/s} = (5 \sin 4\pi t + 20\pi t \cos 4\pi t) \text{ mA}$$

At $t = 0.5$,

$$i = 5 \sin 2\pi + 10\pi \cos 2\pi = 0 + 10\pi = 31.42 \text{ mA}$$

Voltage

- The voltage V_{ab} between two points a and b in an electric circuit is the energy (or work) needed to move a unit charge from a to b; mathematically,

$$v_{ab} \triangleq \frac{dw}{dq}$$

- 1 volt = 1 joule/coulomb = 1 newton-meter/coulomb

Voltage

- Voltage (or potential difference) is the energy required to move a unit charge through an element, measured in volts (V).

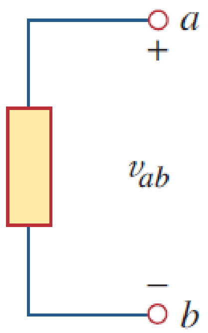

Figure 1.6
Polarity of voltage v_{ab}.

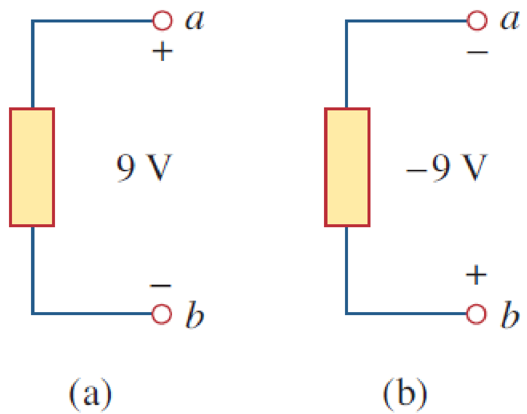

Figure 1.7
Two equivalent representations of the same voltage v_{ab}: (a) Point a is 9 V above point b; (b) point b is -9 V above point a.

Power and Energy

- Power is the time rate of expending or absorbing energy, measured in watts (W).

$$\boxed{p \triangleq \frac{dw}{dt}}$$

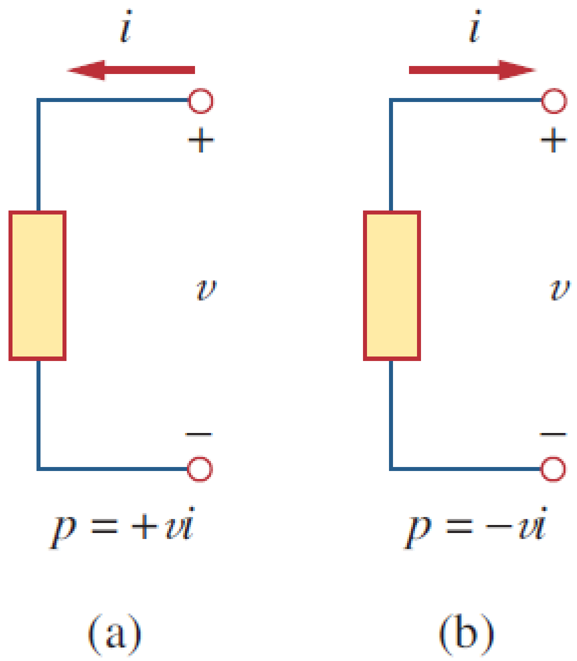

Figure 1.8
Reference polarities for power using the passive sign convention: (a) absorbing power, (b) supplying power.

Power and Energy

- By the passive sign convention, current enters through the positive polarity of the voltage. In this case, *p=+vi* or *p=vi>0* implies that the element is absorbing power.
- However, if *p=-vi* or *vi<0* or , as in Fig. 1.8(b), the element is releasing or supplying power.

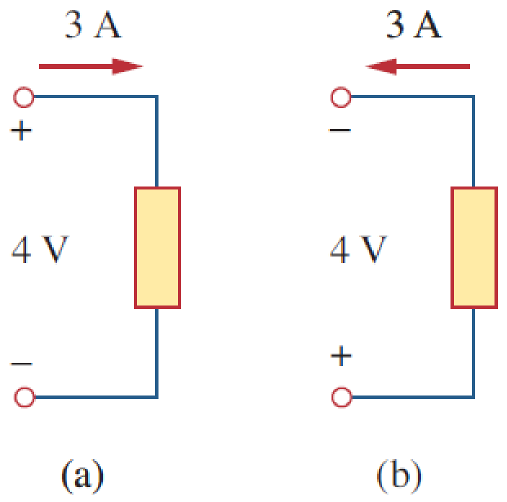

Figure 1.9
Two cases of an element with an absorbing power of 12 W: (a) $p = 4 \times 3 = 12$ W, (b) $p = 4 \times 3 = 12$ W.

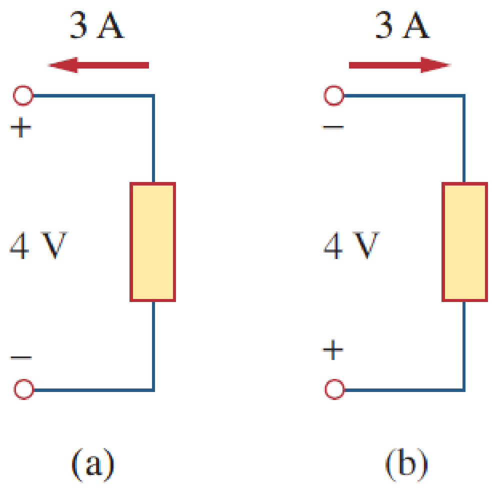

Figure 1.10
Two cases of an element with a supplying power of 12 W: (a) $p = -4 \times 3 = -12$W, (b) $p = -4 \times 3 = -12$ W.

Power and Energy

- The law of conservation of energy must be obeyed in any electric circuit.
- For this reason, the algebraic sum of power in a circuit, at any instant of time, must be zero:

$$\boxed{\sum p = 0}$$

$$w = \int_{t_0}^{t} p\, dt = \int_{t_0}^{t} vi\, dt$$

Power and Energy

- Energy is the capacity to do work, measured in joules (J).
- The electric power utility companies measure energy in watt-hours (Wh), where-

$$\mathbf{1\ Wh = 3{,}600\ J}$$

Power and Energy

Find the power delivered to an element at $t = 3$ ms if the current entering its positive terminal is

$$i = 5 \cos 60\pi t \text{ A}$$

and the voltage is: (a) $v = 3i$, (b) $v = 3\, di/dt$.

Power and Energy

Solution:

(a) The voltage is $v = 3i = 15 \cos 60\pi t$; hence, the power is

$$p = vi = 75 \cos^2 60\pi t \text{ W}$$

At $t = 3$ ms,

$$p = 75 \cos^2 (60\pi \times 3 \times 10^{-3}) = 75 \cos^2 0.18\pi = 53.48 \text{ W}$$

(b) We find the voltage and the power as

$$v = 3\frac{di}{dt} = 3(-60\pi)5 \sin 60\pi t = -900\pi \sin 60\pi t \text{ V}$$

$$p = vi = -4500\pi \sin 60\pi t \cos 60\pi t \text{ W}$$

At $t = 3$ ms,

$$\begin{aligned} p &= -4500\pi \sin 0.18\pi \cos 0.18\pi \text{ W} \\ &= -14137.167 \sin 32.4^\circ \cos 32.4^\circ = -6.396 \text{ kW} \end{aligned}$$

Circuit Elements

- An electric circuit is simply an interconnection of the elements.
- Two types of elements in electric circuits:
  - ✓ *Passive* elements= resistors, capacitors, and inductors
  - ✓ *active* elements = generators, batteries, and operational amplifiers
- An active element is capable of generating energy while a passive element is not.

Circuit Elements

- The most important active elements are voltage or current sources that generally deliver power to the circuit connected to them.
- There are two kinds of sources: independent and dependent sources.

Circuit Elements

- **Independent Sources-** An ideal independent source is an active element that provides a specified voltage or current that is completely independent of other circuit elements.

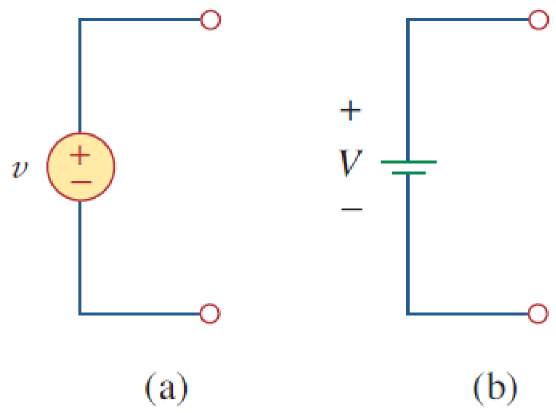

Figure 1.11
Symbols for independent voltage sources: (a) used for constant or time-varying voltage, (b) used for constant voltage (dc).

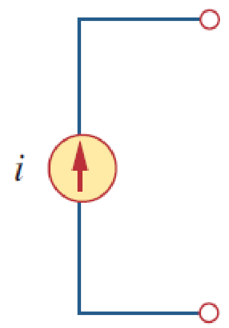

Figure 1.12
Symbol for independent current source.

Circuit Elements

- **Dependent Sources-** An ideal dependent (or controlled) source is an active element in which the source quantity is controlled by another voltage or current.

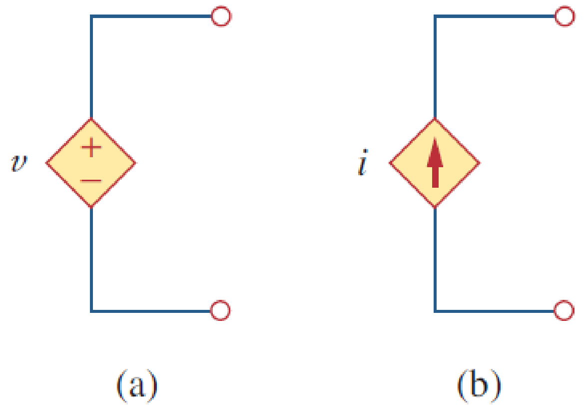

Figure 1.13
Symbols for: (a) dependent voltage source, (b) dependent current source.

Circuit Elements

There are four possible types of dependent sources, namely:

i. A voltage-controlled voltage source (VCVS).
ii. A current-controlled voltage source (CCVS).
iii. A voltage-controlled current source (VCCS).
iv. A current-controlled current source (CCCS).

Circuit Elements

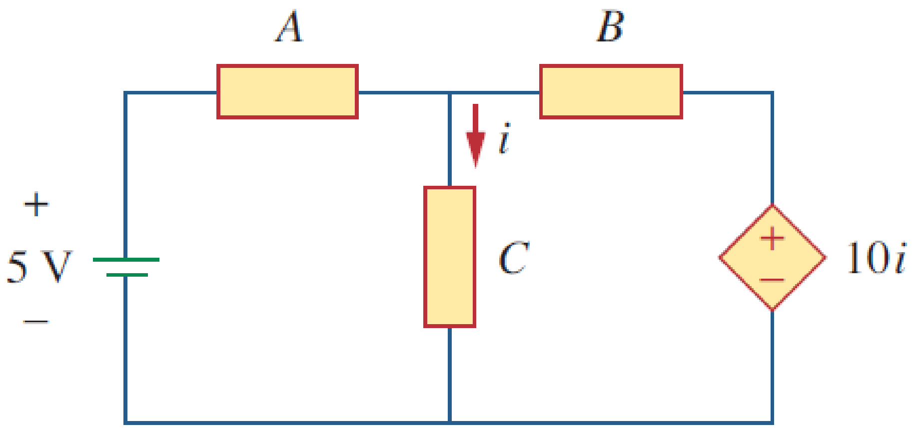

Figure 1.14
The source on the right-hand side is a current-controlled voltage source.

Circuit Elements

Calculate the power supplied or absorbed by each element in Fig. 1.15.

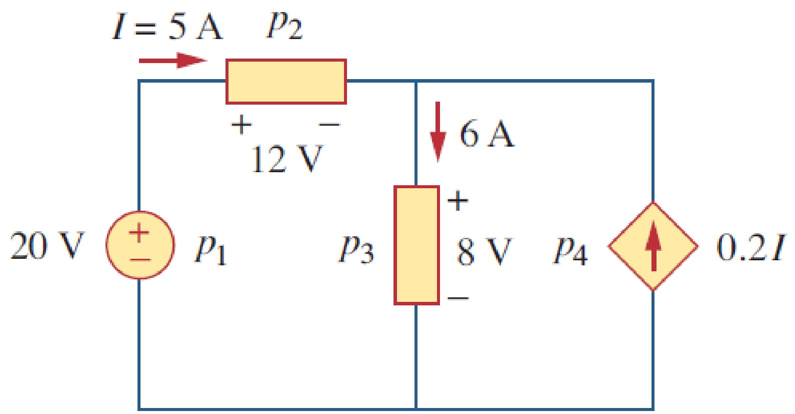

Figure 1.15
For Example 1.7.

Circuit Elements

Solution:

We apply the sign convention for power shown in Figs. 1.8 and 1.9. For p_1, the 5-A current is out of the positive terminal (or into the negative terminal); hence,

$$p_1 = 20(-5) = -100 \text{ W} \qquad \text{Supplied power}$$

For p_2 and p_3, the current flows into the positive terminal of the element in each case.

$$p_2 = 12(5) = 60 \text{ W} \qquad \text{Absorbed power}$$

$$p_3 = 8(6) = 48 \text{ W} \qquad \text{Absorbed power}$$

Circuit Elements

$$p_4 = 8(-0.2I) = 8(-0.2 \times 5) = -8 \text{ W} \qquad \text{Supplied power}$$

We should observe that the 20-V independent voltage source and $0.2I$ dependent current source are supplying power to the rest of the network, while the two passive elements are absorbing power. Also,

$$p_1 + p_2 + p_3 + p_4 = -100 + 60 + 48 - 8 = 0$$