Chapter 1

Basic Concepts

Learning goals

- By the end of this chapter, the students should be able to:
- Use appropriate SI units and standard prefixes when calculating voltages, currents, resistances, and powers.
- Explain the relationships between basic electrical quantities: voltage, current, and power.
- Use the appropriate symbols for independent and dependent voltage and current sources.
- Calculate the value of the dependent sources when analyzing a circuit that contain independent and dependent sources.
- Calculate the power absorbed by a circuit element using the passive sign convention.

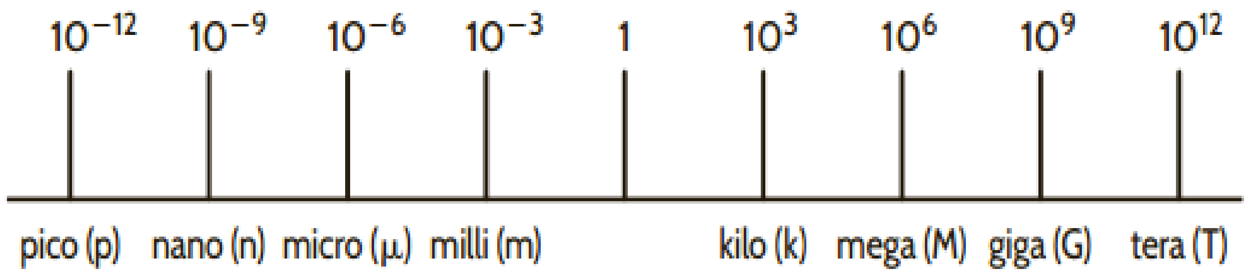
System of Units

- The system of units employed is the international system of units, the Système International des Unités, which is normally referred to as the SI standard system.
- This system is composed of the basic units including meter (m), kilogram (kg), second (s), ampere (A), kelvin (K), candela (cd) etc. These units are well defined in all physics textbooks.

System of Units

Quantity	Quantity symbol	Unit	Unit symbol
Capacitance	C	Farad	F
Charge	Q	Coulomb	C
Current	I	Ampere	A
Electromotive force	E	Volt	V
Frequency	f	Hertz	Hz
Inductance (self)	L	Henry	H
Period	T	Second	s
Potential difference	V	Volt	V
Power	P	Watt	W
Resistance	R	Ohm	Ω
Temperature	T	Kelvin	K
Time	t	Second	s

Standard SI prefixes



- Circuit technology has changed drastically over the years.
- For example, in the early 1960s the space on a circuit board occupied by the base of a single vacuum tube was about the size of a quarter (25-cent coin).

Basic Quantities

- **Electric Circuit and Electric Charge**
- An ***electric circuit*** as an interconnection of electrical components, each of which is described by a mathematical model. The most elementary quantity in an analysis of electric circuits is the electric *charge*.
- An electric circuit is essentially a pipeline that facilitates the transfer of charge from one point to another. The time rate of change of charge constitutes an electric *current*. Mathematically, the relationship is expressed as

Basic Quantities

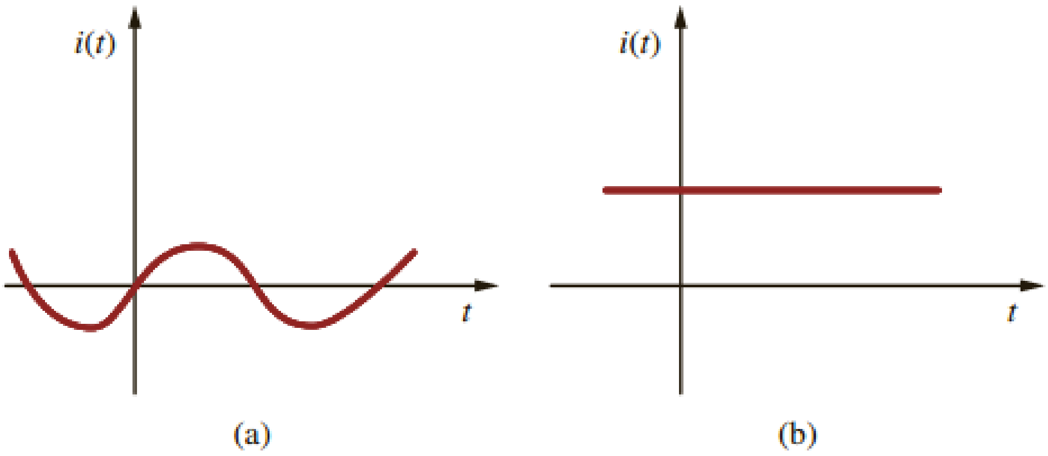
- **Electric Circuit and Electric Charge**
- $i(t) = \frac{dq(t)}{dt} \qquad or \qquad q(t) = \int_{-\infty}^{t} i(x)dx$
- *i* is the current (ampere, A) and *q* is the charge (Coulomb). 1 Ampere is 1 coulomb per second.

Figure a, $I_1=2A$, indicating that 2 C of charge pass from left to right each second.
In Figure. b, $I_2=-3A$ indicating that at any point in the wire shown, 3 C of charge pass from right to left each second.

Basic Quantities

- **Electric Circuit and Electric Charge**
- **Types of current**
- The two types of current that we encounter often in our daily lives are alternating current (ac) and direct current (dc). *Alternating current* is the common current found in every household and is used to run the refrigerator, stove, washing machine, and so on. Batteries, which are used in automobiles and flashlights, are one source of *direct current*.

Basic Quantities



Two common types of current: (a) alternating current (ac); (b) direct current (dc).

Basic Quantities

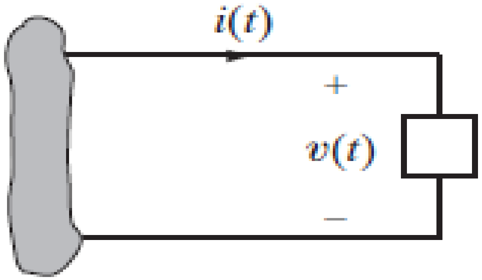
- *Voltage* (also called the *electromotive force*, or *potential*) between two points in a circuit is defined as the difference in energy level of a unit charge located at each of the two points.
- Work or energy, $w(t)$ or W, is measured in joules (J); 1 joule is 1 newton meter (N.m). Hence, voltage [$v(t)$ or V] is measured in volts (V) and 1 volt is 1 joule per coulomb; that is, 1 volt=1 joule per coulomb=1 newton meter per coulomb. If a unit positive charge is moved between two points, the energy required to move it is the difference in energy level between the two points and is the defined voltage.

Basic Quantities

- $v = \frac{dw}{dq}$
- Power is the time rate of change of energy in Joules per second or Watts, W.
- $p = \frac{dw}{dt} = \frac{dw}{dq}\left(\frac{dq}{dt}\right) = vi$

Sign convention for power.

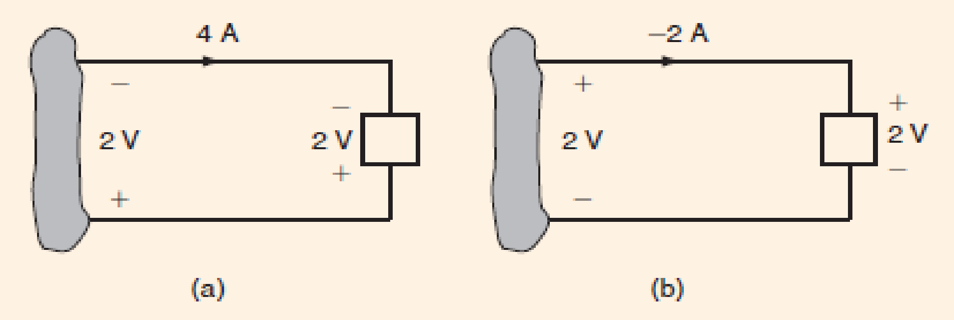
- The passive sign convention shown in figure below is used to determine whether power is being absorbed or supplied.



- The variable for the voltage *v(t)* is defined as the voltage across the element with the positive reference at the same terminal that the current variable *i(t)* is entering. This convention is called the *passive sign convention.*
- If the sign of the power is positive, power is being absorbed by the element; if the sign is negative, power is being supplied by the element.

Sign convention for power.

- **Example**
- Given the two diagrams shown in Fig. below, determine whether the element is absorbing or supplying power and how much.

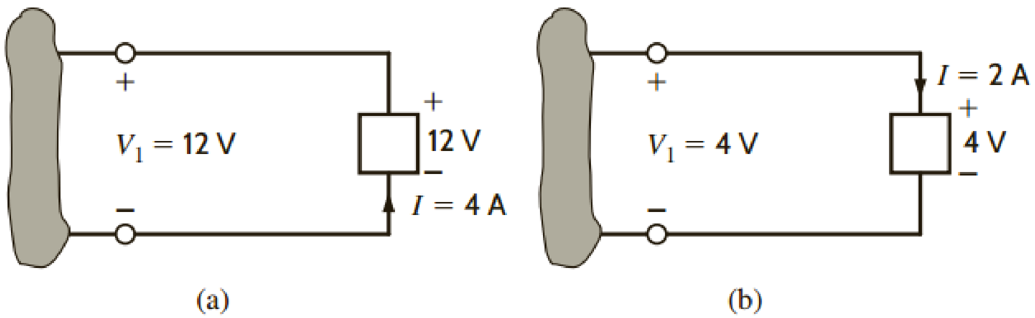


Sign convention for power.

- **Solution**
- In Figure (a) the power is P=(2 V)(–4 A) = –8 W. Therefore, the element is supplying power.
- In Figure (a) the power is P=(2 V)(–2 A) = –4 W. Therefore, the element is supplying power.

Sign convention for power.

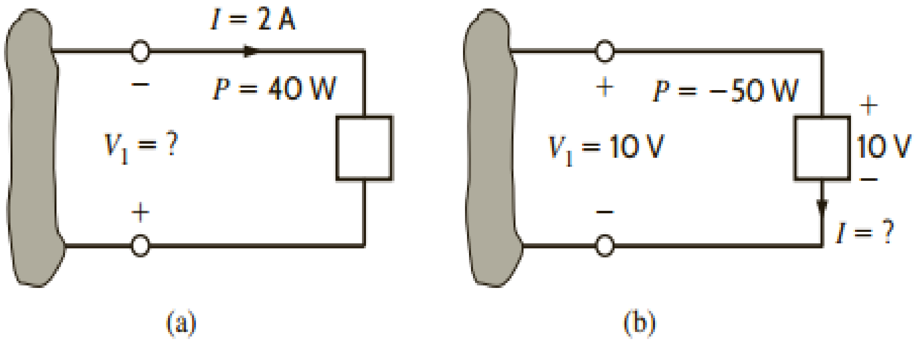
- **Questions**
- Determine the amount of power absorbed or supplied by the elements in Fig. 1.6.



(P=-48 W, 8W).

Sign convention for power.

- Determine the unknown variables in figure below:



(V_1=-20 V, I=-5A)

Tellegen’s Theorem

- The sum of the powers absorbed by all elements in an electrical network is zero.
- Another statement of this theorem is that the power supplied in a network is exactly equal to the power absorbed.

Circuit Elements

- **Passive Circuit Elements**
- Passive elements do not generate any energy. They may either consume energy (i.e. convert from electrical form to a non-electrical form such as heat or light), or store energy (in electrostatic and electromagnetic fields). Examples are:
- ***Resistance*** (unit: *ohm,* Ω; letter symbol: *R* , *r*)
- The basic equation governing the resistor is Ohm’s Law.
- *v(t)* = *R.i(t)*
- $i(t) = G.v(t)$
- $G = \frac{1}{R}$ $is\ the\ conductance\ (unit: Siemen, S)$

Circuit Elements

- ***Inductance*** (unit: *henry*, H; letter symbol: *L* , *l*)
- $v = L\frac{di}{dt}$
- ***Capacitance*** (unit: *farad*, F; letter symbol: *C* , *c*)
- The charge stored is directly proportional to the applied voltage.
- $Q = C.v$
- Since $q = \int i.dt$ the basic equation for the capacitor may be re-written in circuit terms as
- $v = \frac{1}{C}\int i.dt$ $\quad$ *or* $\quad$ $i = C\frac{dv}{dt}$

Circuit Elements

- ***Impedance and Admittance***
- These may all be written in the form
- $v = Z(p)i$ $\quad\quad$ or $\quad\quad$ $i = Y(p)v$
- Where $Z(p)$ is the impedance operator, and $Y(p)$ is the admittance operator.
- Impedances and Admittances may be either linear or non-linear. This is defined based on whether the values of R, L and C (slope of characteristic) are constants or not.

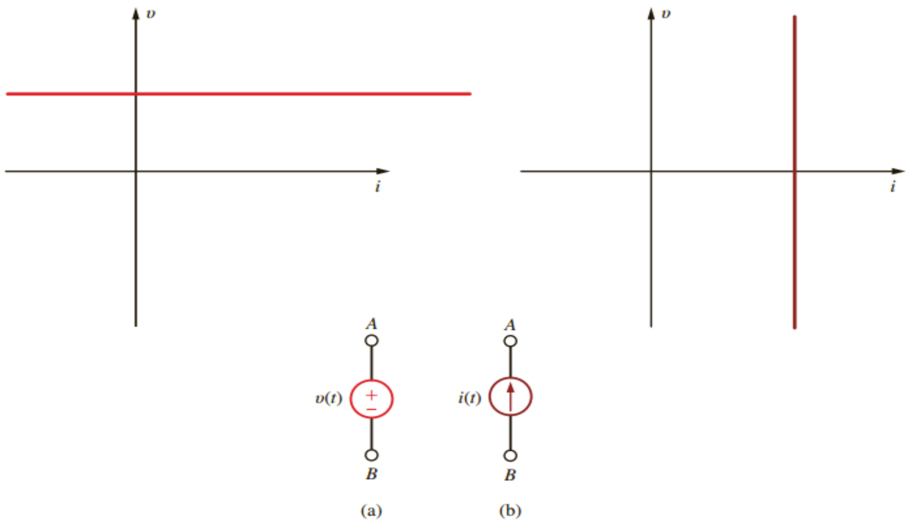
Circuit Elements

- **Active Circuit Elements**
- An *Active Circuit Element* is a component in a circuit which is capable of producing or generating energy. [Producing energy actually means converting non-electrical form of energy to an electrical form].
- Active circuit elements are thus sources of energy (or simply sources) and can be categorised into voltage sources and the current sources.

Circuit Elements

- **Independent sources**
- An *independent voltage source* is a two-terminal element that maintains a specified voltage between its terminals *regardless of the current through it* as shown by the v-*i* plot in Fig. a.
- The *independent current source* is a two terminal element that maintains a specified current *regardless of the voltage across its terminals*, as illustrated by the v-*i* plot in Fig. b.

Circuit Elements

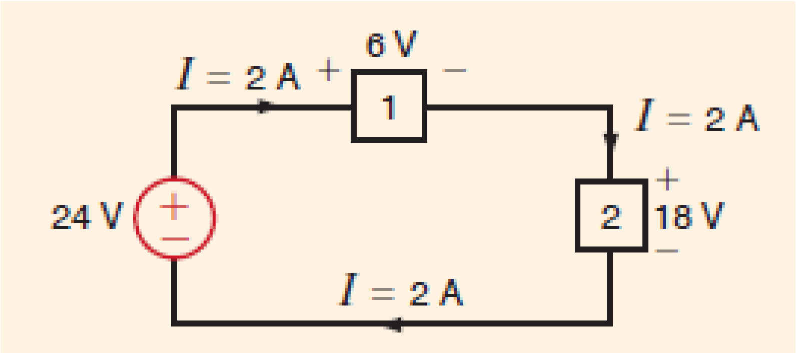


Symbols for (a) independent voltage source, (b) independent current source.

- In their normal mode of operation, independent sources supply power to the remainder of the circuit.
- However, they may also be connected into a circuit in such a way that they absorb power e.g charging battery with another battery.

Examples

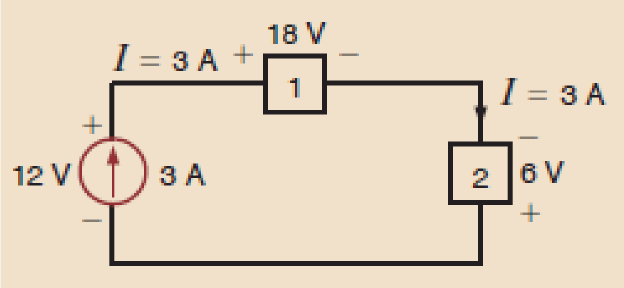
- Determine the power absorbed or supplied by the elements in the network in Fig. below.



Solution: The current flow is out of the positive terminal of the 24-V source, and therefore this element is supplying (2)(24)=48 W of power. The current is into the positive terminals of elements 1 and 2, and therefore elements 1 and 2 are absorbing (2)(6)=12 W and (2)(18)=36 W, respectively. Note that the power supplied is equal to the power absorbed.

Examples

- Find the power that is absorbed or supplied by the elements in Fig. below.



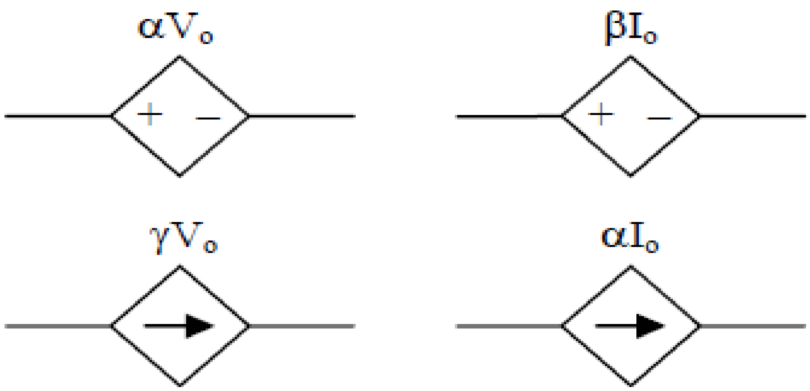
Solution

Current source supplies 36 W, element 1 absorbs 54 W, and element 2 supplies 18 W.

Dependent sources

- Dependent sources generate a voltage or current that is determined by a voltage or current at a specified location in the circuit. There are four possibilities:
- Voltage dependent (controlled) voltage source
- Current dependent (controlled) voltage source
- Voltage dependent (controlled) current source
- Current dependent (controlled) current source

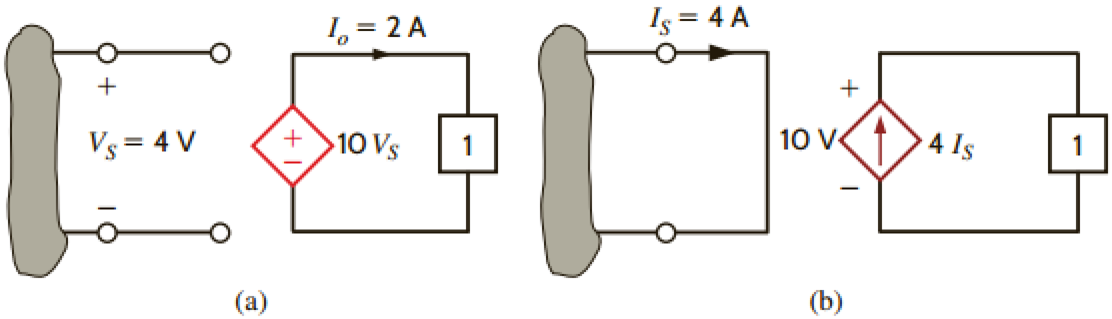
Dependent sources



Dependent sources

Tutorial Questions

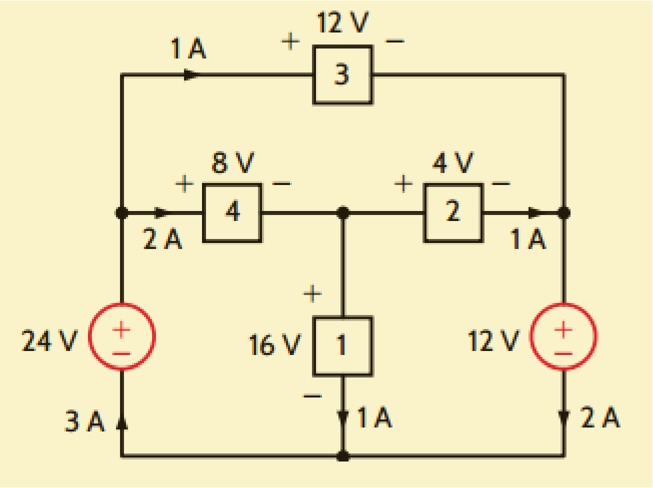
Determine the power supplied by the dependent sources in Fig. below



(a) Power supplied = 80 W;
(b) power supplied = 160 W.

Tutorial Questions

Use Tellegen's theorem to find the current Io in the network in Fig below:

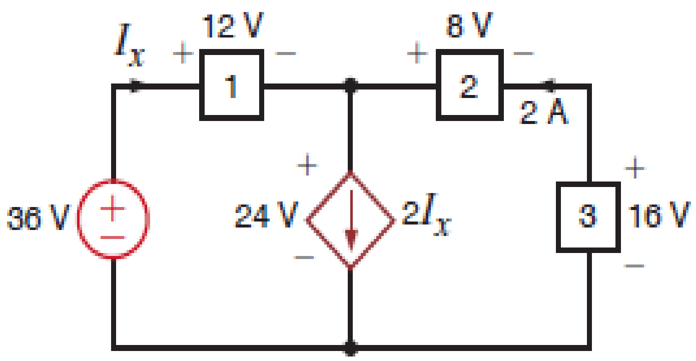


Tutorial Questions

- **Solution**
- First, determine the power absorbed by each element in the network. Using the sign convention for power, we obtain:
- $P_{2A} = (6)(-2) = -12\ W$
- $P_1 = (6)(I_0) = 6I_0$
- $P_2 = (12)(-9) = -108\ W$
- $P_3 = (10)(-3) = -30\ W$
- $P_{4V} = (4)(-8) = -32W$
- $P_{D5} = (8I_x)(11) = (16)(11) = 176\ W$
- Applying Tellegen's theorem
- $-12 + 6I_0 - 108 - 30 - 32 + 176 = 0, I_0 = 1A$

Tutorial Questions

- Determine the power absorbed by element 1 in Fig. below:



Find V_x in the network in Fig. below using Tellegen's theorem.