Basic Laws of Electric Cicuits

Basic Electric Circuit Concepts

System of Units:

We use the SI (System International) units. The system uses meters (m), kilograms (kg), seconds (s), ampere (A), degree kelvin (^{O}K) and candela (cd) as the fundamental units.

We use the following prefixes:

pica (p): 10^{-12}

tera (T): 10^{12}

nano (n): 10^{-9}

giga (G) : 10^{9}

micro (μ): 10^{-6}

mega (M): 10^{6}

milli (m): 10^{-3}

kilo (k): 10^{3}

Basic Electric Circuit Concepts

What is electricity?

One might define electricity as the separation of positive and negative electric charge. (see slide note)

When the charges are separated and stationary we call this static electricity. The charging of a capacitor is an example. The separation of charge between clouds and the earth before a lighting discharge is a static electricity.

When the charges are in motion (changing with time relative to one another) we have variable electricity.

Basic Electric Circuit Concepts

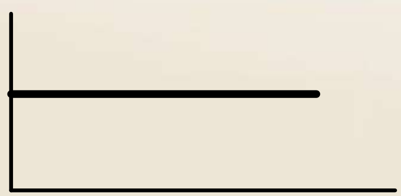
Basic Quantities: Current

The unit of current is the ampere (A). We note that

1 ampere = 1 coulomb/second

We normally refer to current as being either direct (dc) or alternating (ac).

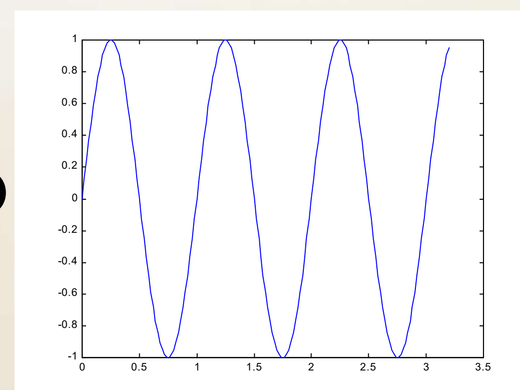
i(t)



t

dc current

i(t)

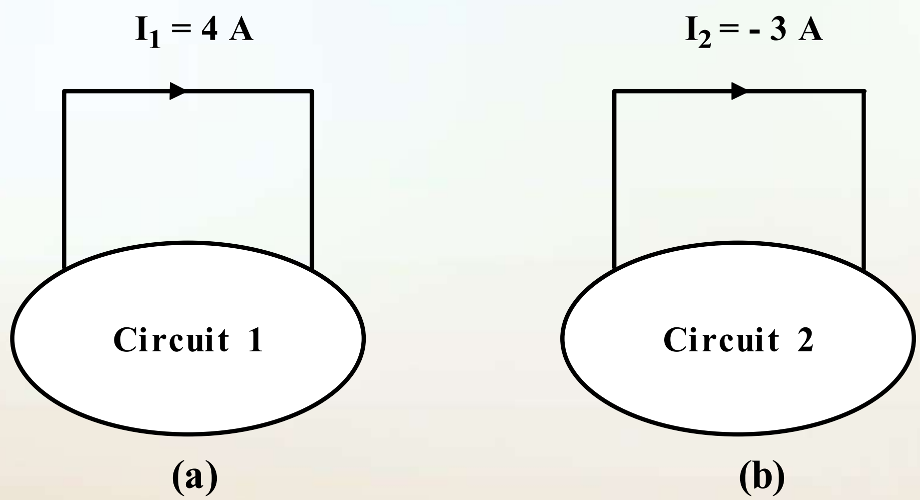


ac current

Basic Electric Circuit Concepts

Basic Quantities: Current

In solving for current in a circuit, we must assume a direction, solve for the current, then reconcile our answer. This is illustrated below.



In the diagram above, current I_1 is actually 4 A as assumed. The actual positive direction of current I_2 (equal to -3 A) in the opposite direction of the arrow for I_2.

<u>Basic Electric Circuit Concepts</u>

<u>Basic Quantities:</u> Voltage

The next quantity of interest is <u>voltage</u>. Voltage is also called an <u>electromotive force</u> (emf). It is also called potential (coming from the expression, "potential energy." However, voltage is not energy.)

Suppose one coulomb of charge is located at point b and one joule of energy is required to move the charge to point a. Then we say that V_{ab} = 1 volt = 1 joule/coulomb = 1 newton.meter/coulomb.

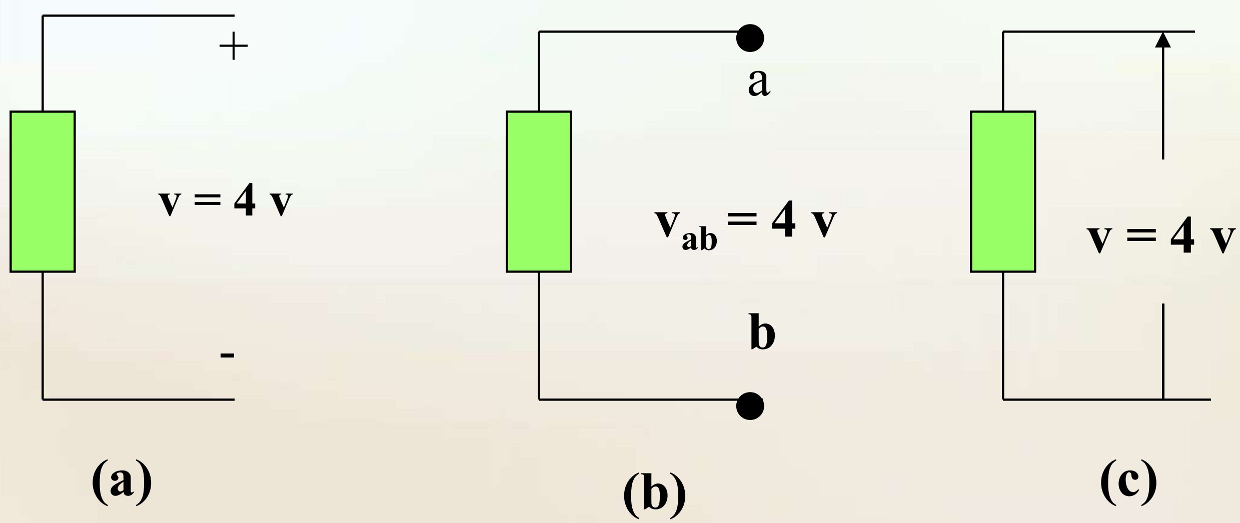
V_{ab} = 1 volt states that the potential of point a (voltage at point a) is l volt (positive) with respect to point b.

The sign associated with a voltage is also called its <u>polarity</u>.

Basic Electric Circuit Concepts

Basic Quantities: Voltage

As in the case for current, we must assume a positive direction (polarity) for the voltage. Consider the three diagrams below.

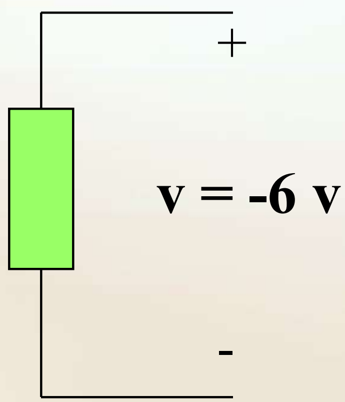


Each of the above gives the same information.

Basic Electric Circuit Concepts

Basic Quantities: Voltage

We need to keep in mind that we assume a polarity for the voltage. When we solve the circuit for the voltage, we may find that the actual polarity is not the polarity we assumed.



The negative sign for 6 v indicates that if the red lead of a voltmeter is placed on + terminal and the black lead on the – terminal the meter will read downscale or –6v. A digital meter would read –6 v. What would an analog meter do?

Basic Electric Circuit Concepts

Basic Quantities: Voltage

In summary, we should remember that,

$$v = \frac{\Delta w}{\Delta q} \qquad \textbf{(2)}$$

This can be expressed in differential form as,

$$v = \frac{dw}{dq} \qquad \textbf{(3)}$$

***w*: energy in joules** ***q*: charge in coulombs**

Basic Electric Circuit Concepts

Basic Quantities: Power

Power is defined as the time rate of change of doing work. We express this as,

$$p = \frac{dw}{dt} \qquad (3)$$

We can write equation (3) as follows:

$$p = \frac{dw}{dq}\frac{dq}{dt} = vi \qquad (4)$$

Power has units of watts.

Basic Electric Circuit Concepts

<u>Basic Quantities:</u> Power

In any closed electric circuit, power is both supplied and absorbed. The amount that is supplied must be equal to the amount that is absorbed.

Stated another way, we can say that the law of conservation of energy must hold. Therefore, in any electric circuit the algebraic sum of the power must be zero.

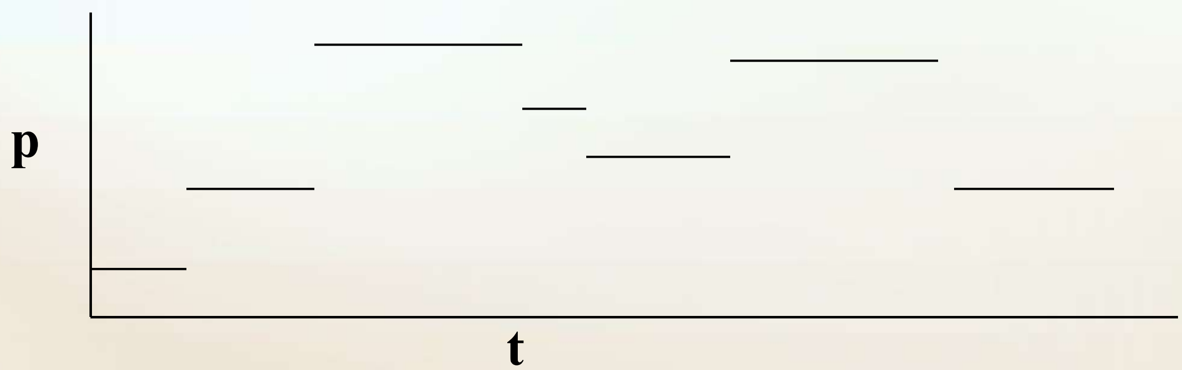
$$\sum p = 0 \qquad (5)$$

Basic Electric Circuit Concepts

<u>Basic Quantities:</u> Power and Energy

When we pay our electric bills we pay for (watt)(hours) but because this is such as large number we usually think kWH. Cost of 1 kWH is approx. 4 – 8 cents.

A profile of the power you use during a day may be as shown below.



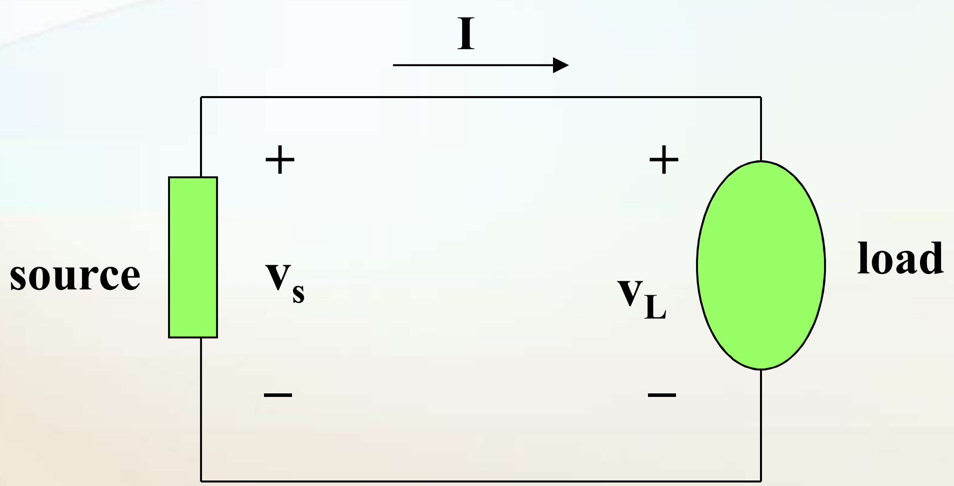
The energy we pay for is the area under the power-time curve.

$$w = \int_{t_o}^{t} p\,dt = \int_{t_o}^{t} vi\,dt \qquad (6)$$

Basic Electric Circuit Concepts

Basic Quantities: Power

We adopt a passive sign convention in order to define the sign of supplied power and the sign of absorbed power. Consider the following.



***Power supplied*: If the assumed direction of the current leaves the assumed positive polarity of the voltage, power is supplied.**

***Power absorbed*: If the assumed direction of the current enters the assumed positive polarity of the voltage, power is absorbed.**

Basic Electric Circuit Concepts

Basic Quantities: Charge

Charge is the most fundamental quantity of electric circuits. In most electric circuits, the basic charge is that of an electron, which is -1.602×10^{-19} coulombs (C).

The entity, charge, is expressed as Q or q. If the charge is constant we use Q. If the charge is in motion we use q(t) or q.

According to fundamental laws, charge cannot be either created or destroyed, only transferred from one point to another.

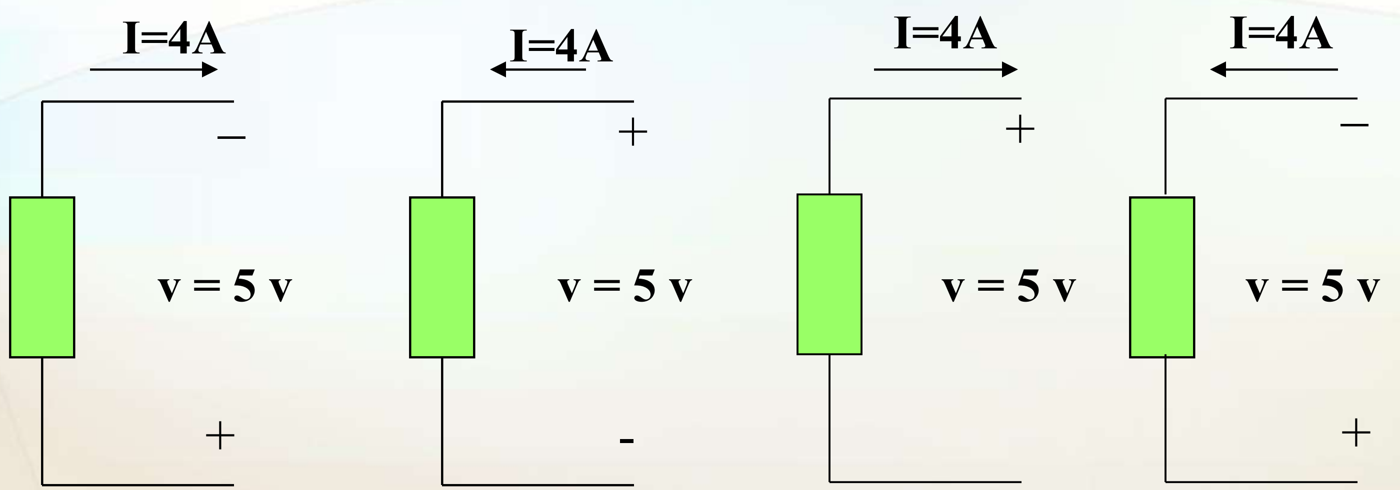
We define charge in motion as current. That is,

$$i(t) = \frac{dq}{dt} \tag{7}$$

Basic Electric Circuit Concepts

Basic Quantities: Power

We consider the following examples:



(a) P = 20W absorbed

(b) P = 20W absorbed

(c) P = -20W absorbed

(d) P = -20W absorbed

Basic Electric Circuit Concepts

Circuit Elements:

We classify circuit elements as passive and active.

Passive elements cannot generate energy. Common examples of passive elements are resistors, capacitors and inductors. We will see later than capacitors and inductors can store energy but cannot generate energy.

Active elements can generate energy. Common examples of active elements are power supplies, batteries, operational amplifiers.

For the present time we will be concerned only with sources. The types of sources we consider are independent and dependent.

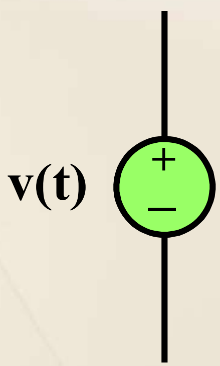
Basic Electric Circuit Concepts

Circuit Elements: **Ideal independent voltage source**

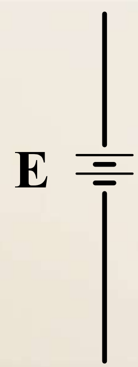
An *ideal dependent voltage source* is characterized as having a constant voltage across its terminals, regardless of the load connected to the terminals.

The ideal voltage source can supply any amount of current. Furthermore, the ideal independent voltage source can supply any amount of power.

The standard symbols of the ideal independent voltage source are shown below.



Most often used



Sometimes used

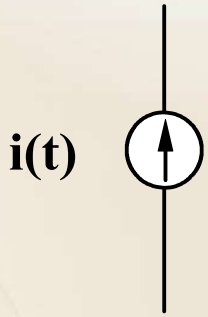
Basic Electric Circuit Concepts

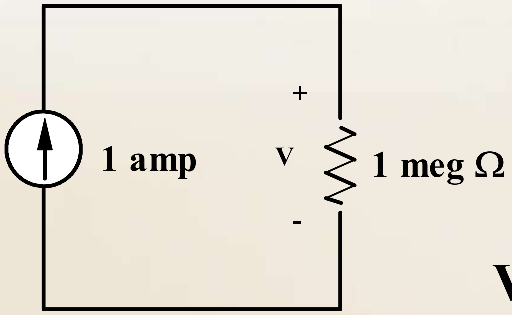
Circuit Elements: **Ideal independent current sources**

An ideal independent current source is characterized as providing a constant value of current, regardless of the load.

If the current source is truly ideal, it can provided any value of voltage and any amount of power.

The standard symbol used for the ideal independent current source is shown below.



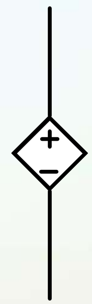


V = ?

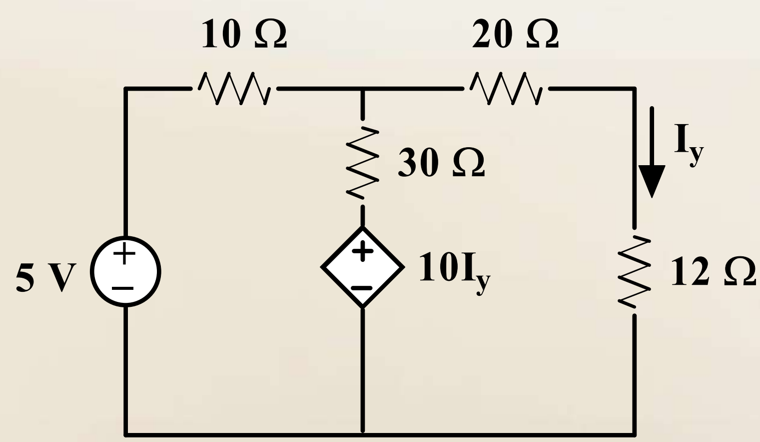
Basic Electric Circuit Concepts

Circuit Elements: Dependent voltage source

A dependent voltage source is characterized by depending on a voltage or current somewhere else in the circuit. The symbol For the current source is shown below. Note the diamond shape.



A circuit containing a dependent voltage source is shown below.

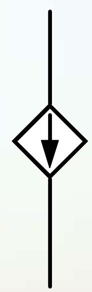


A circuit with a current controlled dependent voltage source.

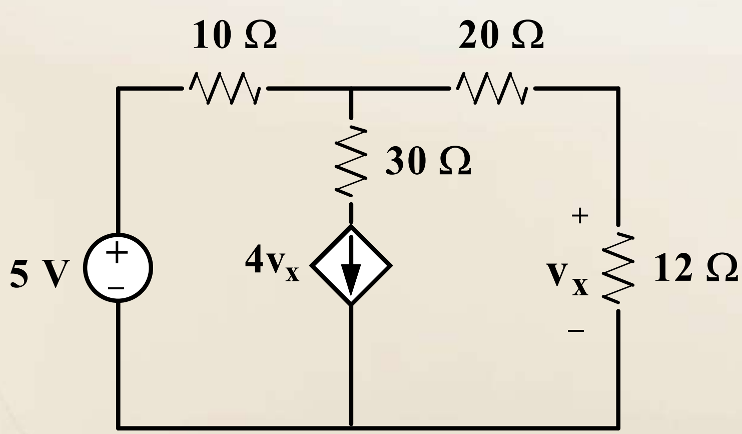
Basic Electric Circuit Concepts

Circuit Elements: Dependent current source

A dependent current source is characterized by depending on a voltage or current somewhere else in the circuit. The symbol for a dependent current source is shown as follows:



A circuit containing a dependent current source is shown below.



A circuit with a voltage controlled dependent current source