BASICS OF ELECTRIC CIRCUITS

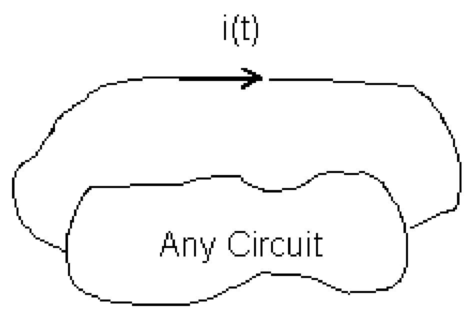
Text: *Basic Engineering Circuit Analysis, 8th edition by J. D. Irwin and R. M. Nelms*

Basic concepts:

(Refer to sections 1, 2 and 3 in chapter 1 of your text)

Electric circuit:

A circuit is an interconnection of electrical components.



Electric charge: is one of the fundamental quantities and exists in every atom.

Symbol: Q or q

Unit: Coulomb (C).

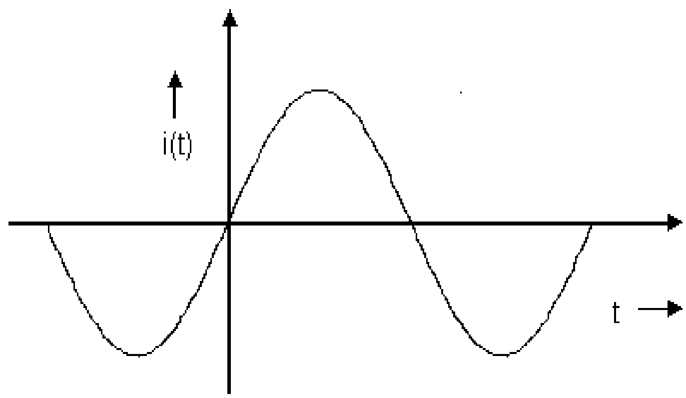
Electric Current: The time rate of change of charge. $i(t) = \frac{dq}{dt}$

Symbol: $i(t)$ or i or I depending on whether the current is constant or time varying quantity.

Unit: Ampere (A); $1 \cdot A = \frac{1 \cdot C}{1 \cdot s}$

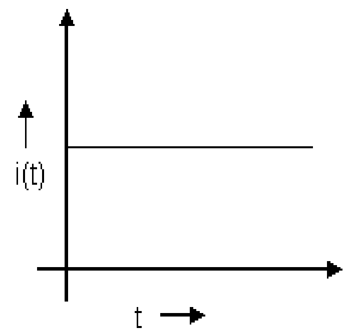
Types of currents: → Alternating current (ac)

→ Direct current (dc)



Alternating Current

Current waveform can be a sine or a cosine function.

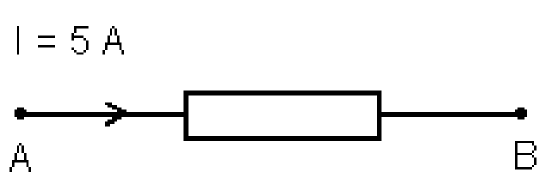


Direct Current

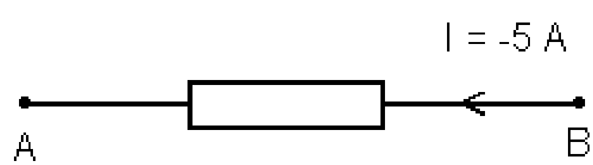
Current has a steady level.

Current flow in a conductor (wire or any element) is specified by two indicators.

1. Direction of current flow, and
2. Value (magnitude)
    - For ac currents, the magnitude varies with time
    - For dc currents, current has a steady value



5A current flows from point A to point B; this is same as a negative current of magnitude 5A flowing from B to A.



Voltage (Potential Difference):

Voltage => Work done on q to move it from point A to point B per unit charge

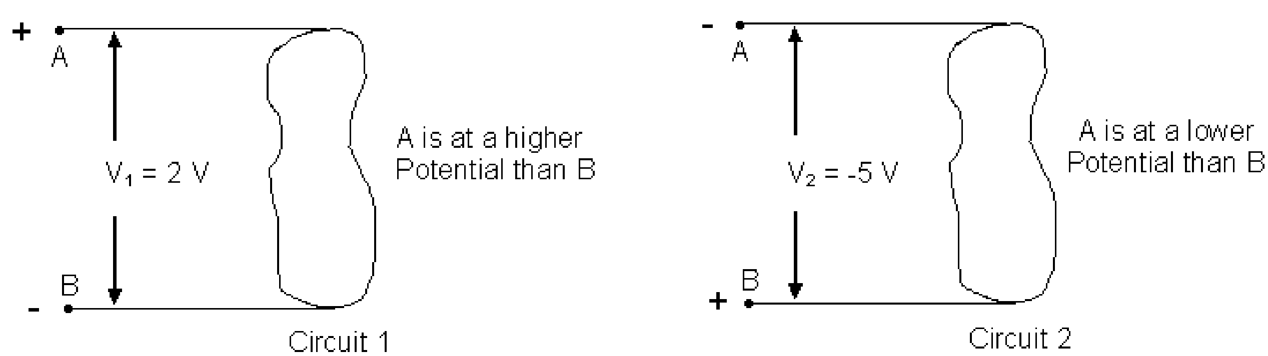
=> Difference in potential energy per unit charge

Symbol: V or $v(t)$

Unit: Volt (V); $1 \cdot V = \frac{1 \cdot J}{1 \cdot C}$

Representation of a potential in a circuit:

Consider the following example.



In representing a potential, it is important to identify both the polarity (direction) and the magnitude.

If we are dealing with a differential amount of charge and energy, then

$$v = \text{voltage} = \frac{dw}{dq}$$

dw = work done

dq = change

By multiplying both sides by current,

$$\therefore v \cdot i = \frac{dw}{dq}\left(\frac{dq}{dt}\right) = \frac{dw}{dt} \Rightarrow \text{Power, } p$$

Power: The time rate of change of energy is defined as power.

Symbol: *P* or *p*.

Unit: Watts (W).

1 *W* = 1 J / 1 *s*.

In general *i*, *v* and *p* are used to represent time varying parameters.

∴ Change in energy from time t_1 to t_2

$$\Delta w = \int_{t1}^{t2} p \cdot dt = \int_{t1}^{t2} v \cdot i dt$$

Power can be equated to the product of current and voltage.

In ac circuits,

$$p(t) = i(t) \cdot v(t)$$

(Voltage and current are considered as time varying parameters). Alternatively, we can define the power in ac circuits in a more specific form later, in terms of *voltage, current and power factor.*

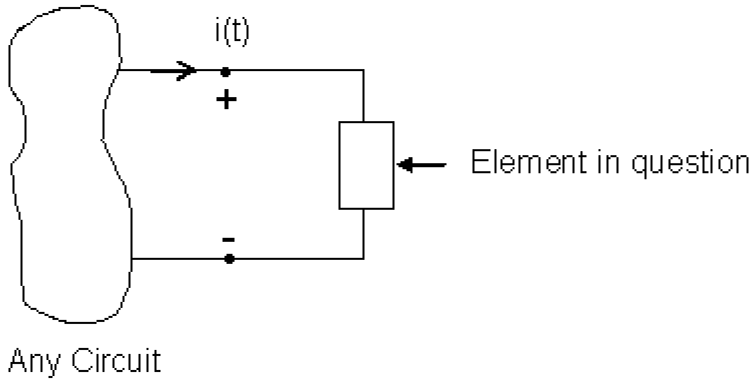
In dc circuits,

$P = I \cdot V$ in dc circuits (steady values)

Hence the unit of power can be defined as:

∴ 1 W = 1 V. 1 A

Sign convention for Power:
(Passive Sign Convention)



In the above illustration, does the element absorb power or supply power?

$p(t) = v(t) \,.\, i(t)$ Or simply, $p = v \cdot i$

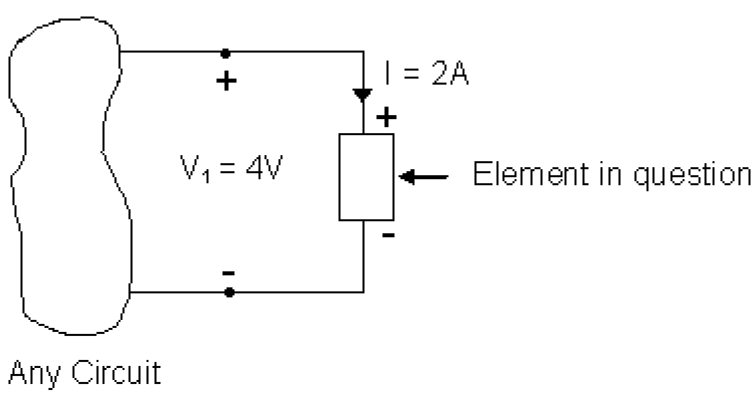
The product of $v \cdot i$ with their attendant signs, defines the magnitude and sign of the power.

If $p(t)$ is positive, then the element absorbs power.

If $p(t)$ is negative, then the element supplies power to the rest of the circuit.

Examples:

(a)

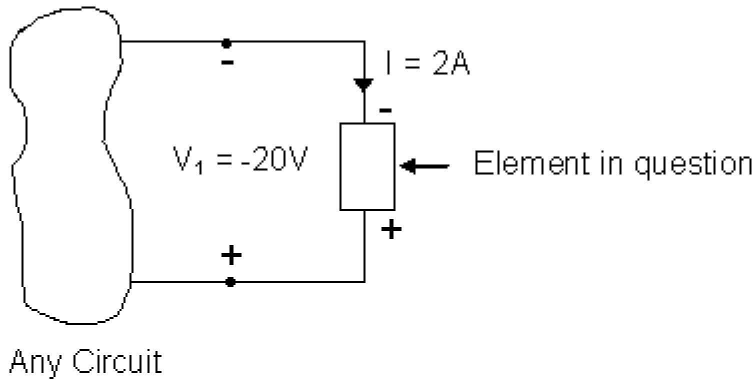


Voltage across the element = 4 V

Current through the element = 2A with "arrow" as marked.

$P = (4V)(2A) = (8W) \Rightarrow$ Since is positive, the element absorbs the power.

(b)



Voltage across the element = - 20V

Current through the element = 2A

BUT, the current enters at a negative terminal; hence, P = - (V I)

$$\therefore P = (-(-20V))(2A) = 40W$$

Circuit Elements:

- Active elements (Sources)
- Passive elements (Loads)

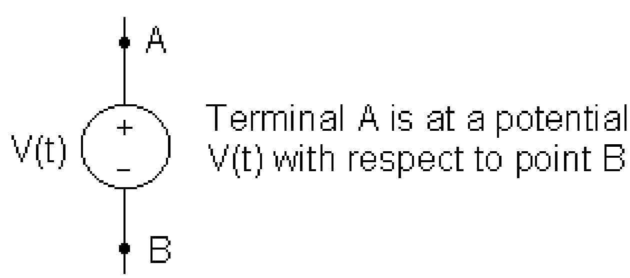
Active elements: Voltage Sources and Current Sources

=> Can be of two types; *independent* or *dependent* sources.

Independent Sources:

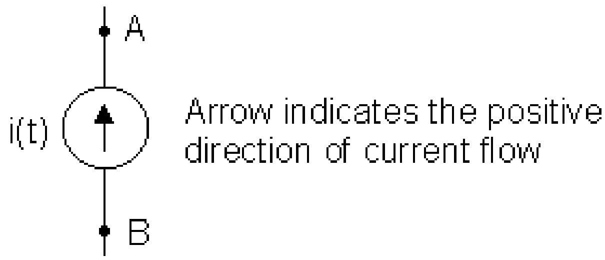
Independent Voltage Sources:

Such sources are two terminal components that maintain a specified voltage across their terminals, independent of the current.



Independent Current Sources:

Such sources are two terminal components that supply a specified current regardless of the voltage across the terminals.



Dependent Sources:

Dependent Voltage Source:

Dependent or controlled voltage sources have a voltage across them which depends on a variable, *x* (voltage or current) elsewhere in the circuit.

Dependent Current Source:

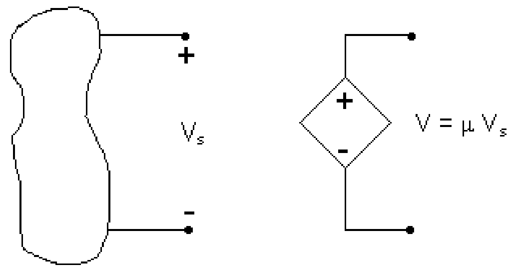
Similarly, dependent current sources have a current, which depends on a variable, *x* (voltage or current) elsewhere in the circuit.

⇒ Often you find these in electronic circuits as representative models for transistors.

Examples of circuits with different types of dependent sources are presented below.

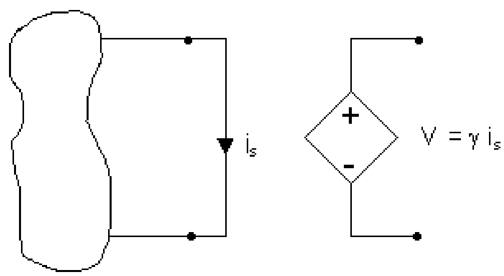
Dependent Sources:

(a) Voltage Dependent Voltage Source

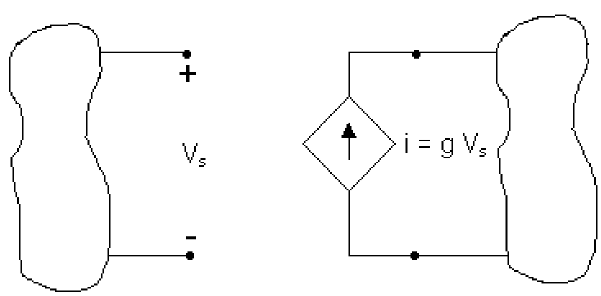


The parameter μ represents voltage to voltage ratio

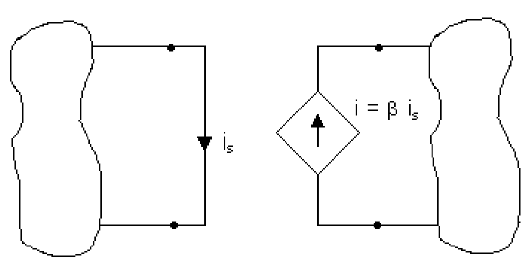
(b) Current dependent Voltage Source



(c) Voltage Dependent Current Source



(d) Current dependent current source



The parameter β represents current to current ratio