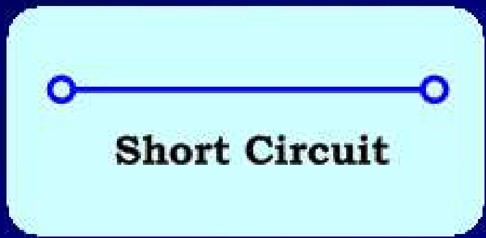
The Short Circuit

When a resistor has zero resistance (i.e. R = 0Ω) we call it a short circuit.

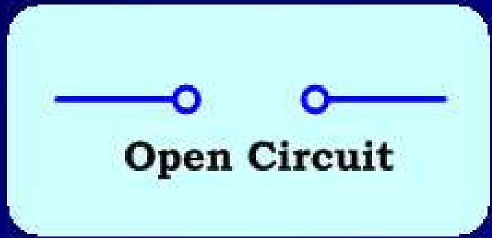


The current through a short circuit is generally not equal to zero. However, the voltage across a short circuit is always equal to zero, because:

$$V = IR = I \times 0 = 0$$

The Open Circuit

When a resistor has an infinite resistance (i.e. R = ∞) we call it an open circuit.



The voltage across an open circuit is generally not equal to zero. However, the current through an open circuit is always equal to zero, because:

$$I = \frac{V}{R} = \frac{V}{\infty} = 0$$

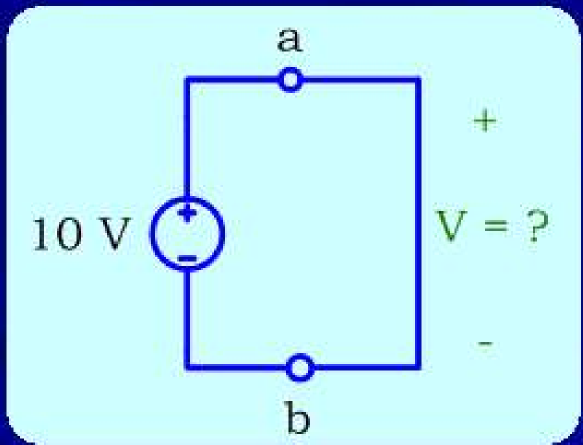
The Open and Short Circuit

When the 10V ideal voltage source is connected to a short circuit as shown below, we immediately face a problem.

What is the voltage across the load in this case ? Is the voltage 'V' 10V or 0V?

This is an ambiguous question which cannot be answered.

It is invalid in this course to connect a short circuit across the terminals of an ideal voltage source. However, as we shall see later, we are allowed to connect a short circuit across the terminals of a realistic voltage source.

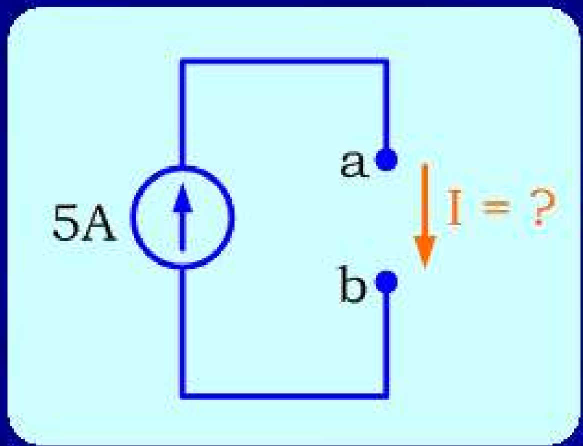


The Open and Short Circuit

The same type of problem faces us, when we connect a 5A current source to an open circuit load, as shown in the figure below,

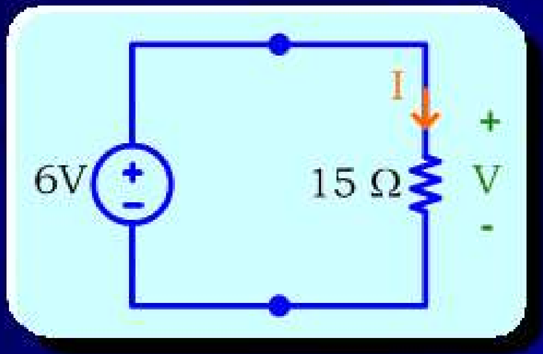
What is the current 'I' through the load in this case? Is it 5A or 0A?

There is no answer to this question also. Thus, it is also invalid in this course to connect an open circuit to the terminals of an ideal current source.



Self Test

Calculate the unknown quantities in the following circuit



Circuit (a)

- A $V = -6V, \ I = 0.4A$
- B $V = 6V, \ I = 0.4A$
- C $V = 6V, \ I = 90A$
- D $V = 6V, \ I = 2.5A$

Electric Circuit 1
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LECTURE 02
ENERGY AND POWER-
OHM'S LAW

- Topics
- Energy and power in electric circuit
- Ohm’s law

After finishing this lecture, you should be able to:

- Understand the relation between power and energy
- Understand the passive sign convention
- Use the passive sign convention in power calculation
- Determine if the power is actually absorbed or delivered
- Verify power conservation
- Use the passive sign convention in Ohm's Law

Electric Energy and Power

The power $p(t)$ *absorbed by* an electric element and the energy $w(t)$ in the *same* element are related by

$$p(t) = \frac{dw(t)}{dt}$$

Unit of w is Joule (J)

Unit of p is Watt (W)

Unit of t is second (s)

Direction of Power Flow

If the energy $w(t)$ *increases* with time [$w(t)$ has a +ve slope], then

$dw(t)/dt > 0$ => $p(t) > 0$ => power is being actually absorbed by the element

If the energy $w(t)$ *decreases* with time [$w(t)$ has a -ve slope], then

$dw(t)/dt < 0$ => $p(t) < 0$ => power is being actually delivered by the element

$w(t)$ increases <=> power being absorbed

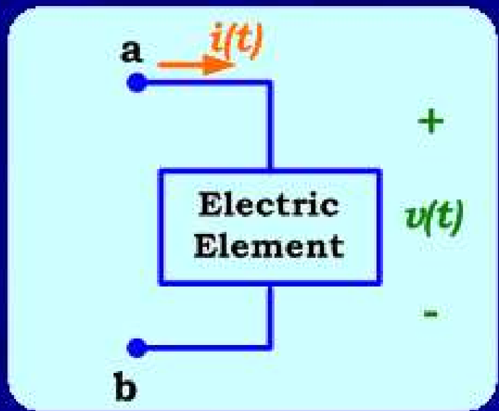
$w(t)$ decreases <=> power being delivered

Relation with v-i

The power ***p(t)*** can be expressed in terms of ***v(t)*** and ***i(t)***

$$p(t) = \frac{dw}{dq}\frac{dq}{dt} = v(t)i(t)$$

The above relation applies *only* when the current enters the element from the (+) terminal and leaves the (-) terminal, as shown below

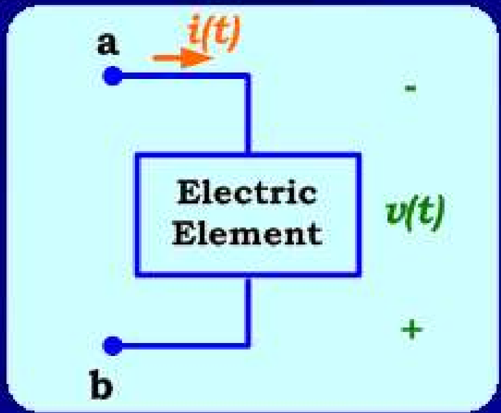


Relation with v-i

If the current enters the element from the (-) terminal and leaves the (+) terminal, as shown below, then we have

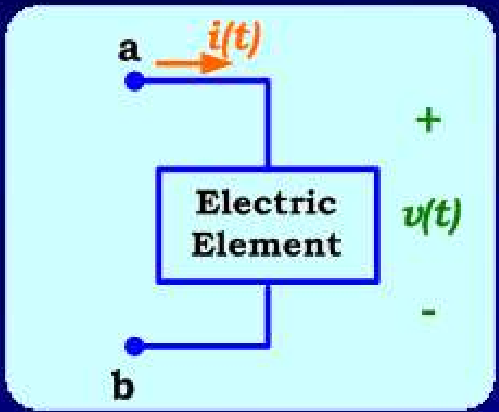
$$p(t) = -v(t)i(t)$$

In this case it is *necessary* to insert a minus sign in the power expression, in order to have consistent results.

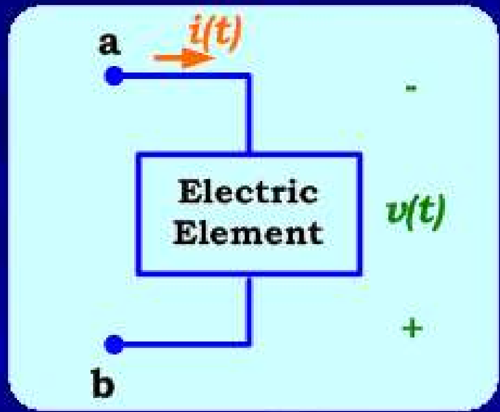


Relation with v-i

Summary



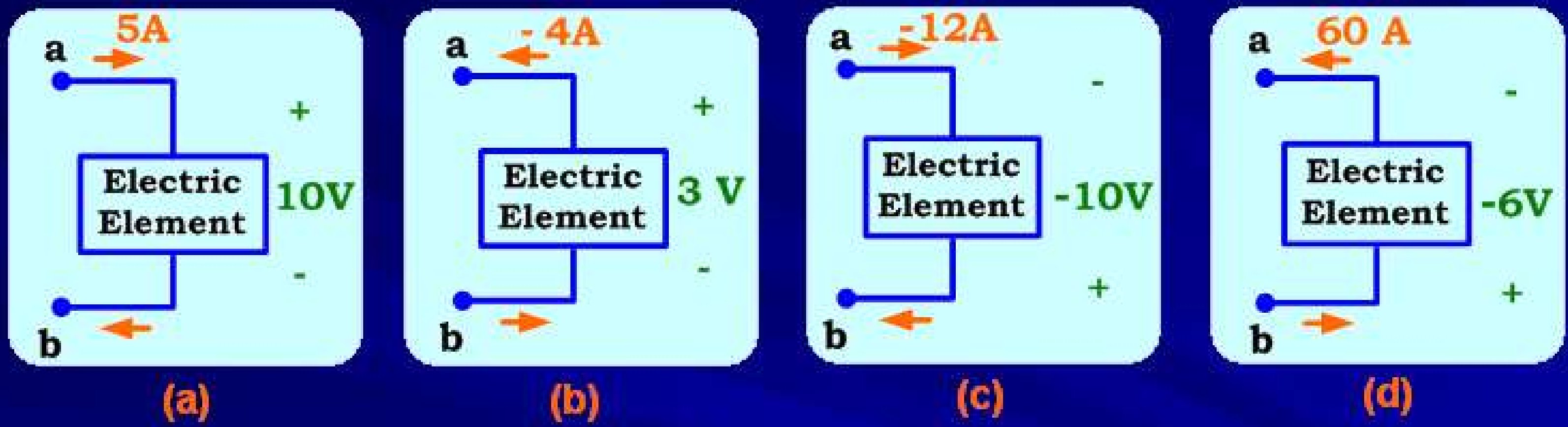
$$p = +v\ i$$



$$p = -v\ i$$

Example 1

Calculate the power absorbed by each element in the given circuits. State whether the power is *actually absorbed* or *delivered* by the element.



Solution:

(a) $p = +i\,v = +(5)(10) = +50\ W$ => $p > 0$ => power actually absorbed

(b) $p = -i\,v = -(-4)(3) = +12\ W$ => $p > 0$ => power actually absorbed

(c) $p = -i\,v = -(-12)(-10) = -120\ W$ => $p < 0$ => power actually delivered

(d) $p = +i\,v = +(60)(-6) = -360\ W$ => $p < 0$ => power actually delivered

Equivalent Statements

The following statements are equivalent

Power *absorbed by* the element

Power *delivered to* the element

Power *dissipated by* the element

Power *consumed by* the element

The following statements are also equivalent

Power *delivered by* the element

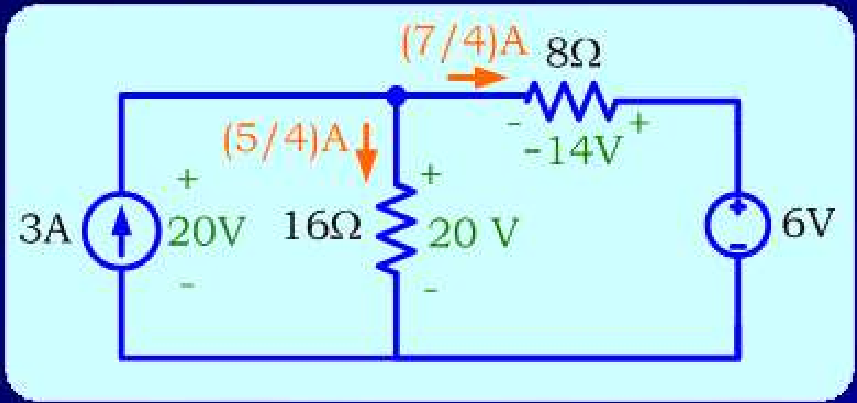
Power *generated by* the element

The symbol p will be reserved for the power absorbed by the element

Example 2

(i) Calculate the power absorbed by each element in the given circuit.

(ii) Show that the total power dissipated is equal to the total power generated



Solution:

(i) $p_{6V} = +iv = +(7/4)(6) = 10.5W$ => dissipated

$p_{3A} = -iv = -(3)(20) = -60W$ => generated

$p_{16W} = +iv = +(5/4)(20) = 25W$ => dissipated

$p_{8W} = -iv = -(7/4)(-14) = 24.5W$ => dissipated

(ii) $\Sigma p_{dis} = 10.5 + 25 + 24.5 = 60W$

$\Sigma p_{gen} = 60W$

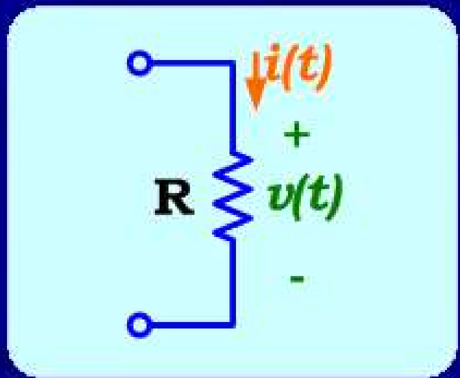
$\Sigma p_{dis} = \Sigma p_{gen}$

Ohm's Law

The voltage ***v(t)*** and current ***i(t)*** in a resistor ***R*** are related by

$$v = iR$$

The above relation is valid *only if* current ***i(t)*** enters the resistor from the (+) terminal and leaves the (-) terminal, as shown below

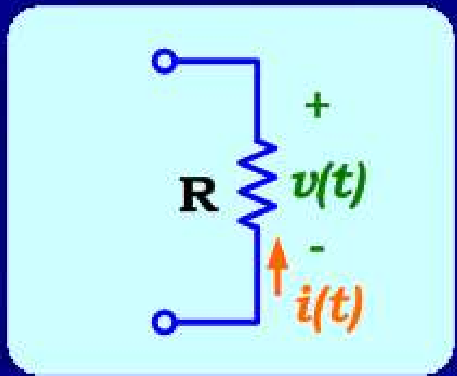


Ohm's Law

If the current ***i(t)*** enters the resistor from the (-) terminal and leaves the (+) terminal, as shown below, then Ohm's law *must be* change to

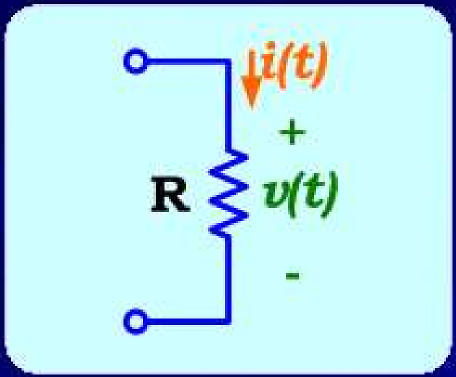
$$v = -iR$$

In this case it is necessary to insert a minus sign in the expression, in order to have consistent results.

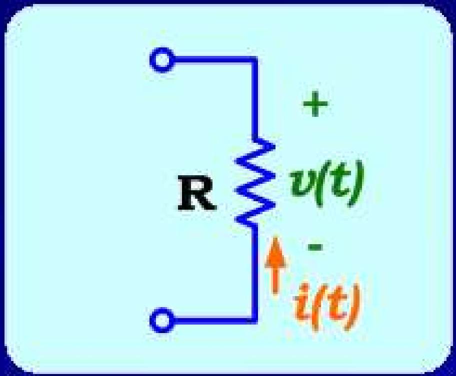


Ohm's Law

Summary



$v = iR$



$v = -iR$

The Passive Sign Convention

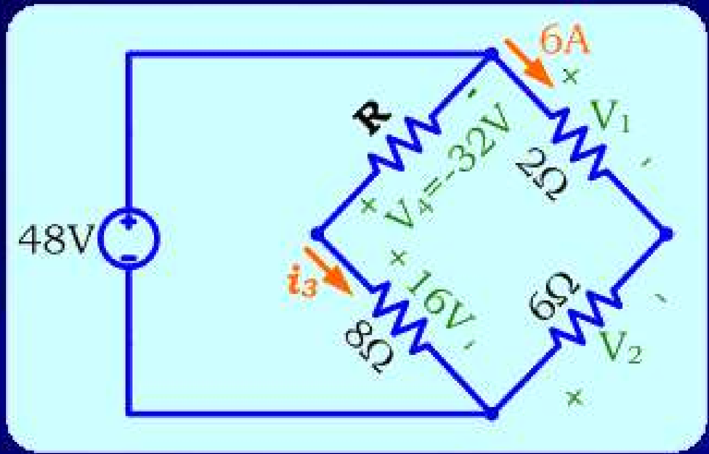
The use of the ± signs in the Ohm's law and the power expression is known as the *passive sign convention*

$i(t)$ enters the (+) terminal $\Rightarrow$ $p = +vi$ and $v = +iR$

$i(t)$ enters the (-) terminal $\Rightarrow$ $p = -vi$ and $v = -iR$

Example

Calculate the unknown quantities in the following circuit



Solution:

$$v_1 = +(6)(2) = 12\text{V}$$

$$i_3 = +\frac{16}{8} = 2\text{A}$$

$$v_2 = -(6)(6) = -36\text{V}$$

$$R = -\frac{v_4}{i_3} = -\frac{(-32)}{2} = 16\Omega$$