Electric Circuit 1
Al-Anbar University

# LECTURE 02

# ENERGY AND POWER-OHMS LAW KIRCHOFFS CURRENT LAW

## Topics

- Energy and power in electric circuits
- Ohm's Law
- Kirchhoff's Current 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
- Apply Kirchhoff's Current Law at a node
- Apply Kirchhoff's Current Law at a supernode

## 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

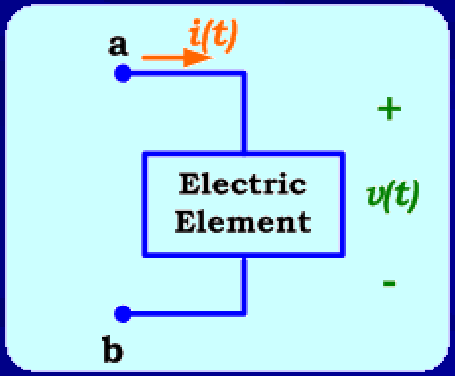
$w(t)$ decreases <=> power being delivered

## 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

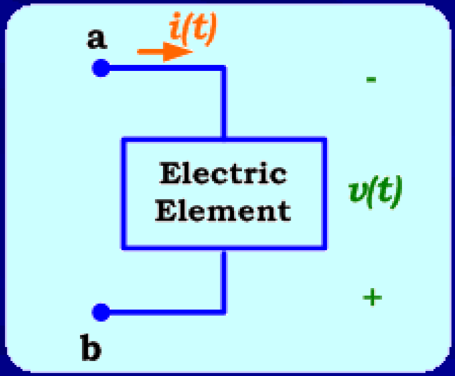


## Relation with v-i

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

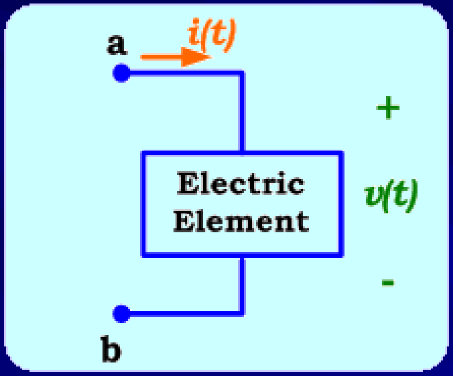
$$p(t) = -v(t)\,i(t)$$

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

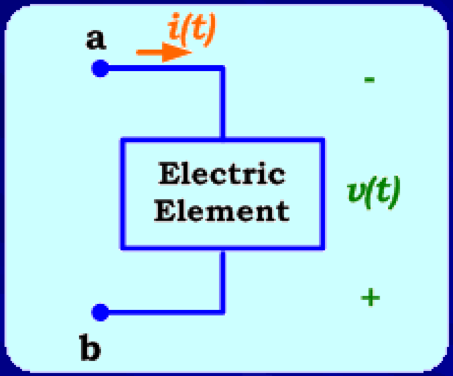


# Relation with v-i

Summary



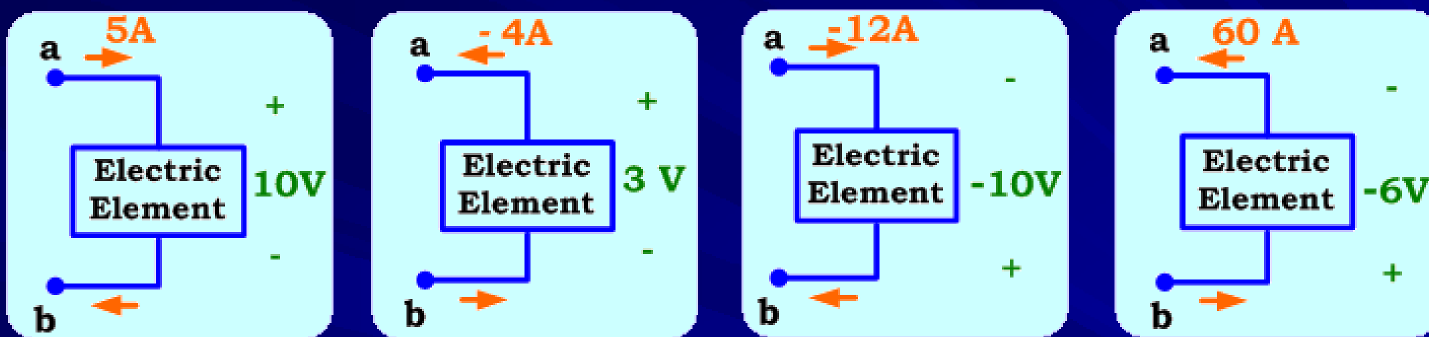

$$p = +v\ i$$




$$p = -v\ i$$

## 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.




(a) (b) (c) (d)

Solution:

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

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

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

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

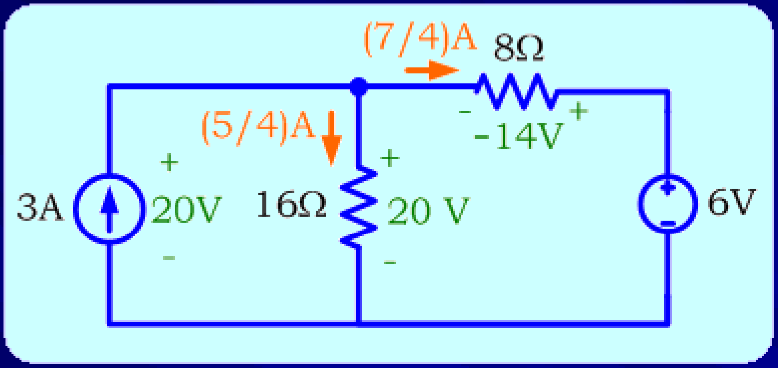
Power *generated by* the element

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) $p_{6V} = +i\,v = +(7/4)(6) = 10.5W$ => 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) $\Sigma\, p_{dis} = 10.5 + 25 + 24.5 = 60W$

$\Sigma\, p_{gen} = 60W$

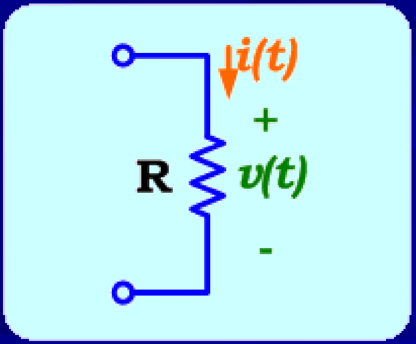
$$\Sigma\, p_{dis} = \Sigma\, p_{gen}$$

## 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

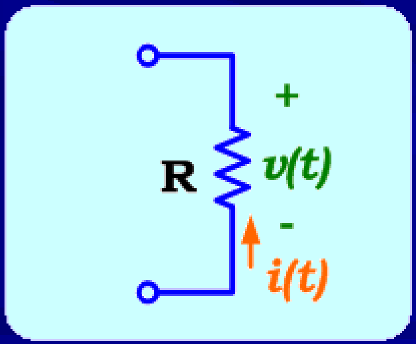


## Ohm's Law

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

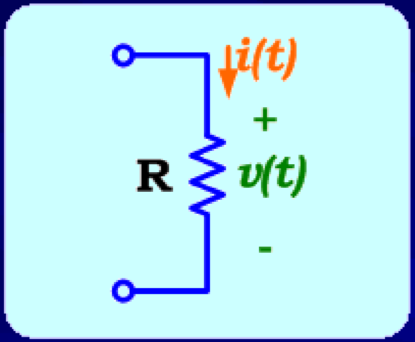
$$v = -iR$$

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

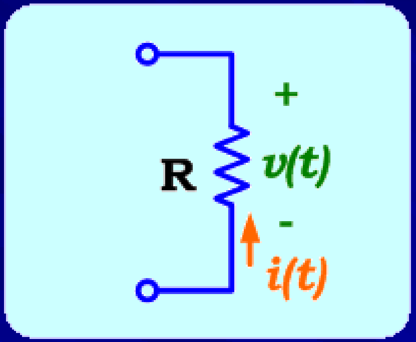


## Ohm's Law

Summary




$v = iR$




$v = -iR$

## The Passive Sign Convention

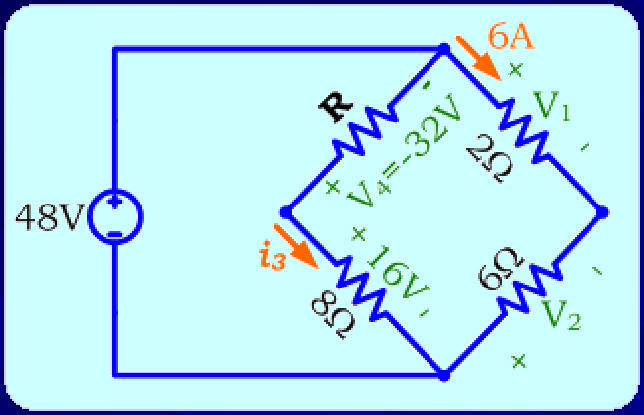
The use of the ± signs in the Ohm's law and the power expression is known as the *passive sign convention*

$i(t)$ 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:

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

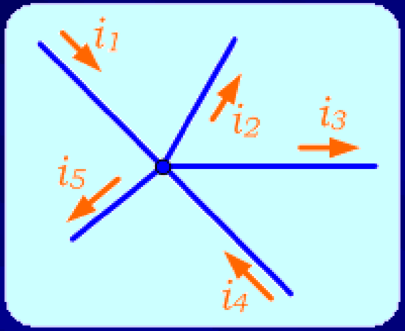
$$i_3 = +\frac{16}{8} = 2\text{A}$$

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

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

## Kirchhoff's Current Law (KCL)

The sum of currents *entering* a node (interconnection of two or more branches) is equal to the sum of currents *leaving* that node




$$i_1 + i_4 = i_2 + i_3 + i_5$$

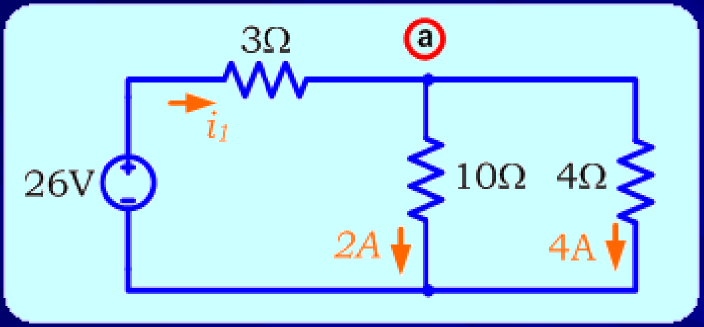
Equivalent Statement of KCL:

The algebraic sum of currents entering a node (currents entering the node is taken as positive) is equal to zero

$$i_1 - i_2 - i_3 + i_4 - i_5 = 0$$

## Example 1

Calculate the unknown current in the following circuit

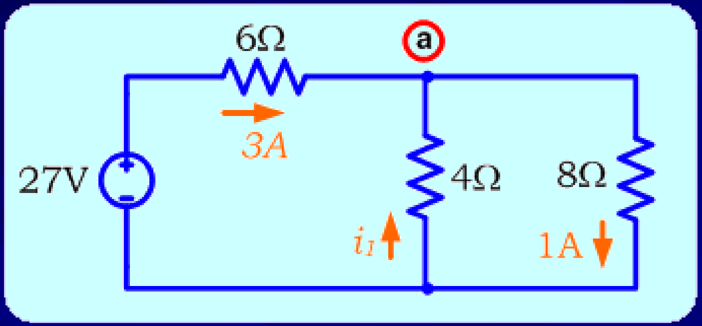



Solution:

KCL at node a $\Rightarrow$ $i_1 = 2 + 4 = 6\,\text{A}$

## Example 2

Calculate the unknown current in the following circuit




Solution:

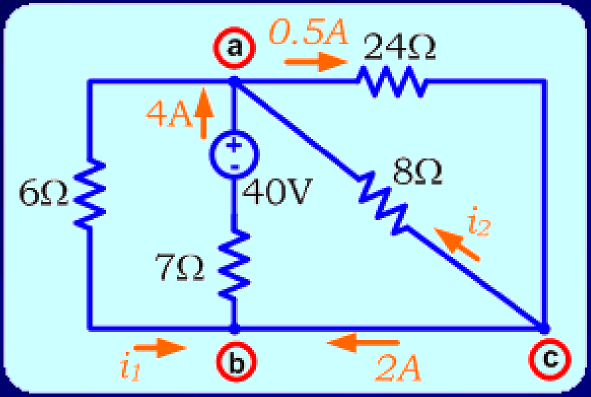
KCL at node a $\Rightarrow 3 + i_1 = 1 \Rightarrow i_1 = -2\,A$

Alternatively,

KCL at node a $\Rightarrow 3 + i_1 - 1 = 0 \Rightarrow i_1 = -2\,A$

## Example 3

Calculate the unknown currents in the following circuit




Solution:

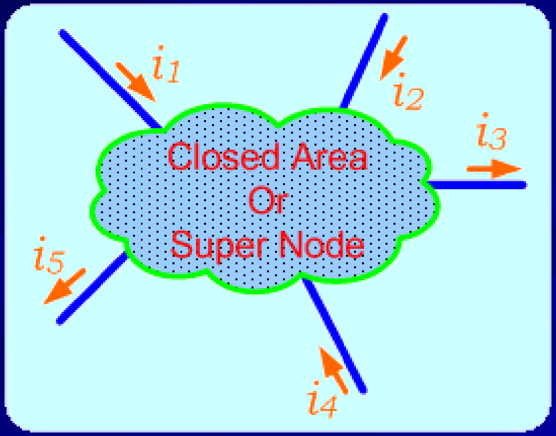
KCL at node b $\Rightarrow i_1 - 4 + 2 = 0 \Rightarrow i_1 = 2A$

KCL at node c $\Rightarrow 0.5 - i_2 - 2 = 0 \Rightarrow i_2 = -1.5A$

Check KCL at node a $\Rightarrow -i_1 + 4 + i_2 - 0.5 = -(2) + 4 + (-1.5) - 0.5 = -4 + 4 = 0$

## Supernode

KCL is also applicable to a *closed area* (super node)

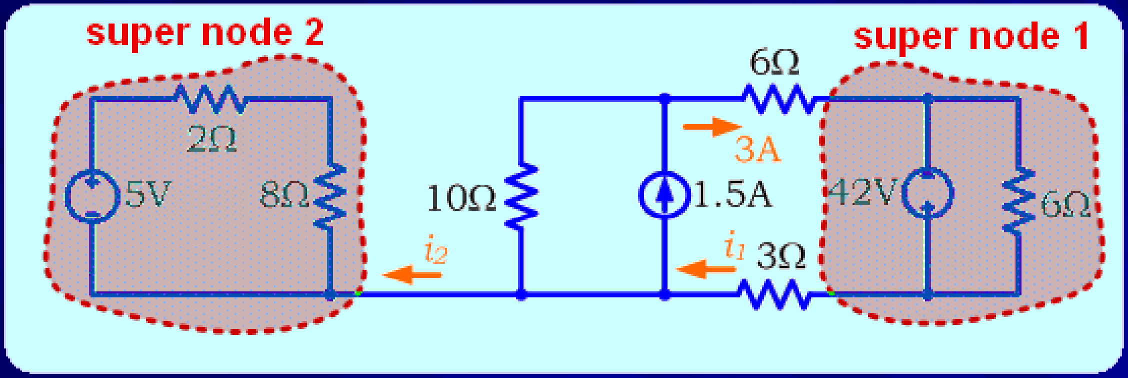



The algebraic sum of currents entering a super node is equal to zero

$$i_1 + i_2 - i_3 + i_4 - i_5 = 0$$

## Example 4

Calculate the unknown currents in the circuit shown below



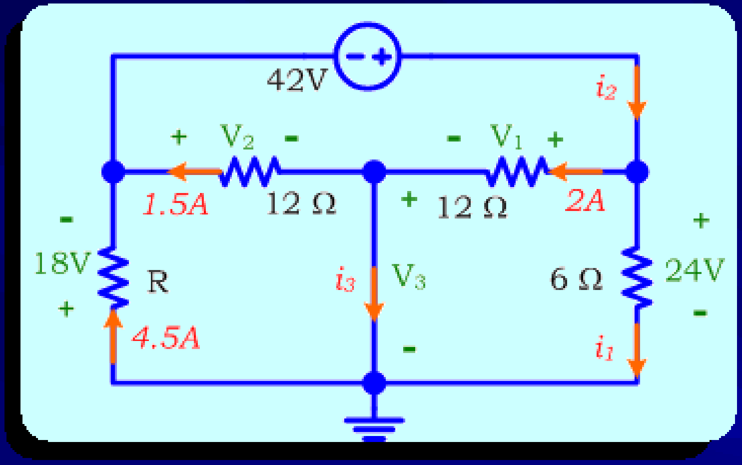

Solution:

KCL at super node 1 $\Rightarrow$ $3 - i_1 = 0$ $\Rightarrow$ $i_1 = 3A$

KCL at super node 2 $\Rightarrow$ $i_2 = 0$ $\Rightarrow$ $i_2 = 0A$

## Self Test

In the circuit shown below, calculate:




(a) $i_1$

- A $i_1 = 144A$
- B $i_1 = -4A$
- C $i_1 = 4A$
- D $i_1 = 1/4\ A$
- E $i_1 = -\ 1/4\ A$