Engineering College
Electrical Engineering
Department

Electric Circuits I

Chapter 1: Basic Concepts of Electric Circuits

Part 1: Circuit Variables

EE 2010 – Credits : 4

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The Overall Goal

Chapter 1 aims to establish a solid understanding of the basic concepts, principles, and analysis techniques in electric circuits, providing a foundation for further study in the field.

The Main Topics

Part 1: Circuit Variables:

- **Circuit Variables:** Introducing the basic variables used in circuit analysis, such as voltage, current, and power.
- **Circuit Analysis:** An Overview: Providing an overview of circuit analysis techniques and methodologies.
- **Voltage and Current:** Explaining the concepts of voltage and current and their relationship in electric circuits.
- **The Ideal Basic Circuit Element:** Introducing the ideal basic circuit elements, such as resistors, capacitors, and inductors.
- **Power and Energy:** Discussing the concepts of power and energy in electric circuits and their calculation methods.

Part 2: Circuit Elements:

- **Voltage and Current Sources:** Explaining different types of voltage and current sources used in circuits.
- **Ohm's Law:** Describing Ohm's law, which relates voltage, current, and resistance in a circuit.
- **Kirchhoff's Laws:** Introducing Kirchhoff's laws, which are fundamental principles used for circuit analysis.
- **Analysis of Circuit Containing Dependent Sources:** Discussing the analysis of circuits that contain dependent sources, which are sources whose values depend on other circuit variables.

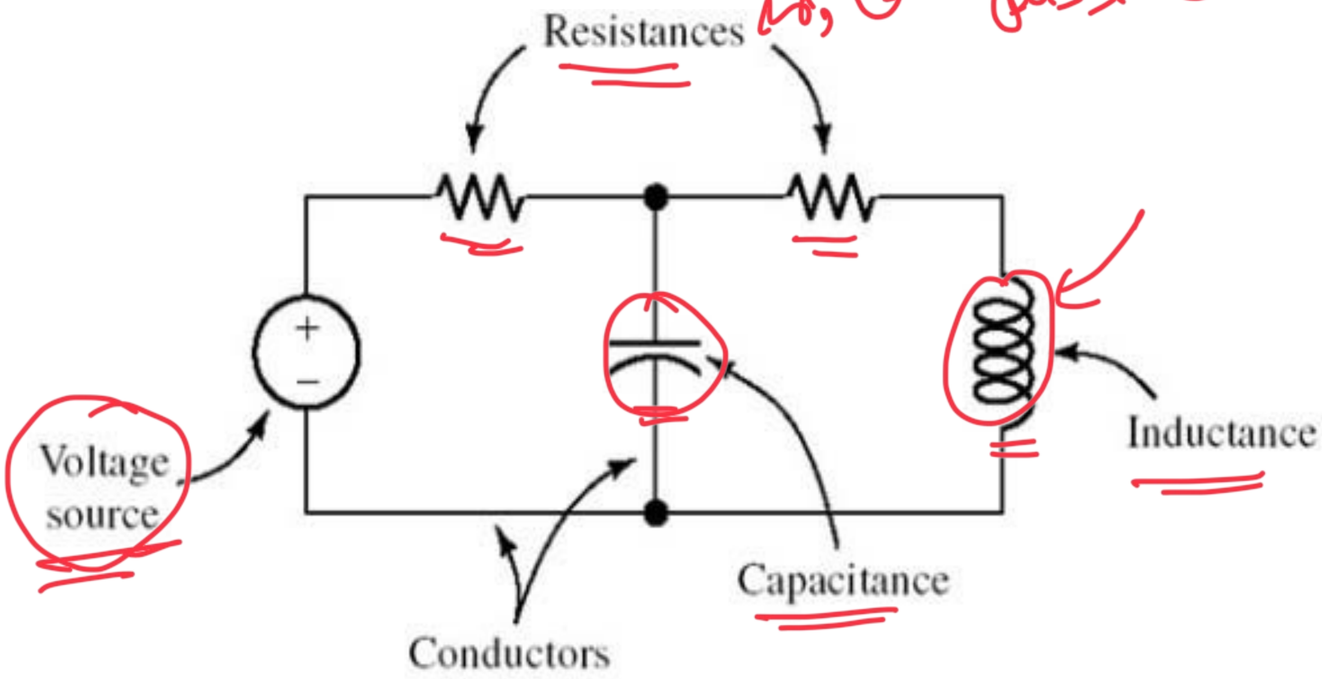
1- Introduction

In the field of electrical engineering, our primary focus is on the transmission and exchange of energy between different locations. In order to accomplish this, an interconnection of electrical devices are required.

An electric circuit is a system of interconnected components, where each component is called an **element**.

In fact, Electrical circuits are composed of electrical generators (**sources**) and components that can be passive, non-reactive such as resistors or reactive passive such as capacities and inductions.

passive



2- Circuit variables

The circuit variables are : **Current, Voltage, Power and Energy; (I, V, P, E)**

a) Voltage (V)

Definition: Voltage, also known as electric potential difference, is the force that drives the electric current (**the energy per unit charge)**

Symbol: V

Unit: Volt(V)

Formula: $\boxed{V = \frac{dW}{dq}}$, V: voltage in volt, W: the energy in Joule, q: the charge in Coulomb

شحنة ، q

مقدار التغير في الجهد

لنقل الالكترونات

2- Circuit variables

b) Current (I)

Definition: Electric current in the flow of electric charge through a conductor, It is mesured in amperes (A),

Symbol: I

Unit: Ampere (A)

Formula: $I = \frac{dq}{dt}$, I: the current in Ampere, q: the charge in Coulomb, t: the time in second

Reminder of Knowledge

https://www.youtube.com/watch?v=MUh_dOcqgVw

Electric current is defined as the flow of electric charge through a conductor.

The direction of a current is opposite to the direction of electron flow.

The SI unit of electric current is the ampere (A).

One ampere is equivalent to one coulomb of electric charge passing through a point in a circuit per second.

Mathematically, electric current (I) is expressed as:

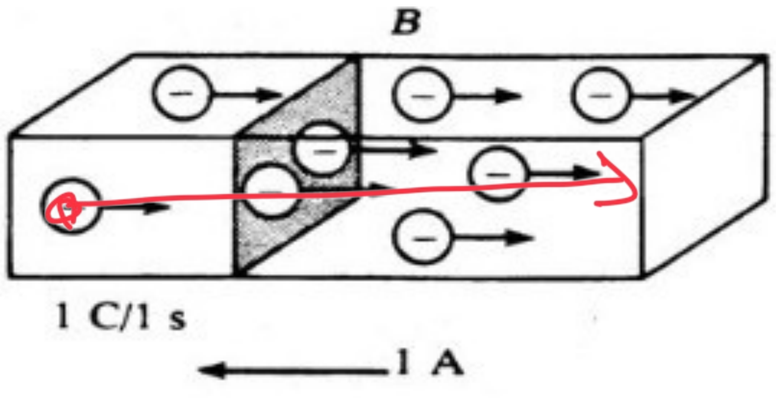
$$\boxed{i = \frac{dq}{dt},}$$

where

i = the current in amperes,

q = the charge in coulombs,

t = the time in seconds.



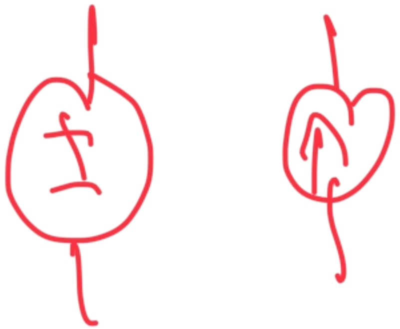
(b)

Negative ions

Reminder of Knowledge

والقيمة

https://www.youtube.com/watch?v=7VEdfuE9bic



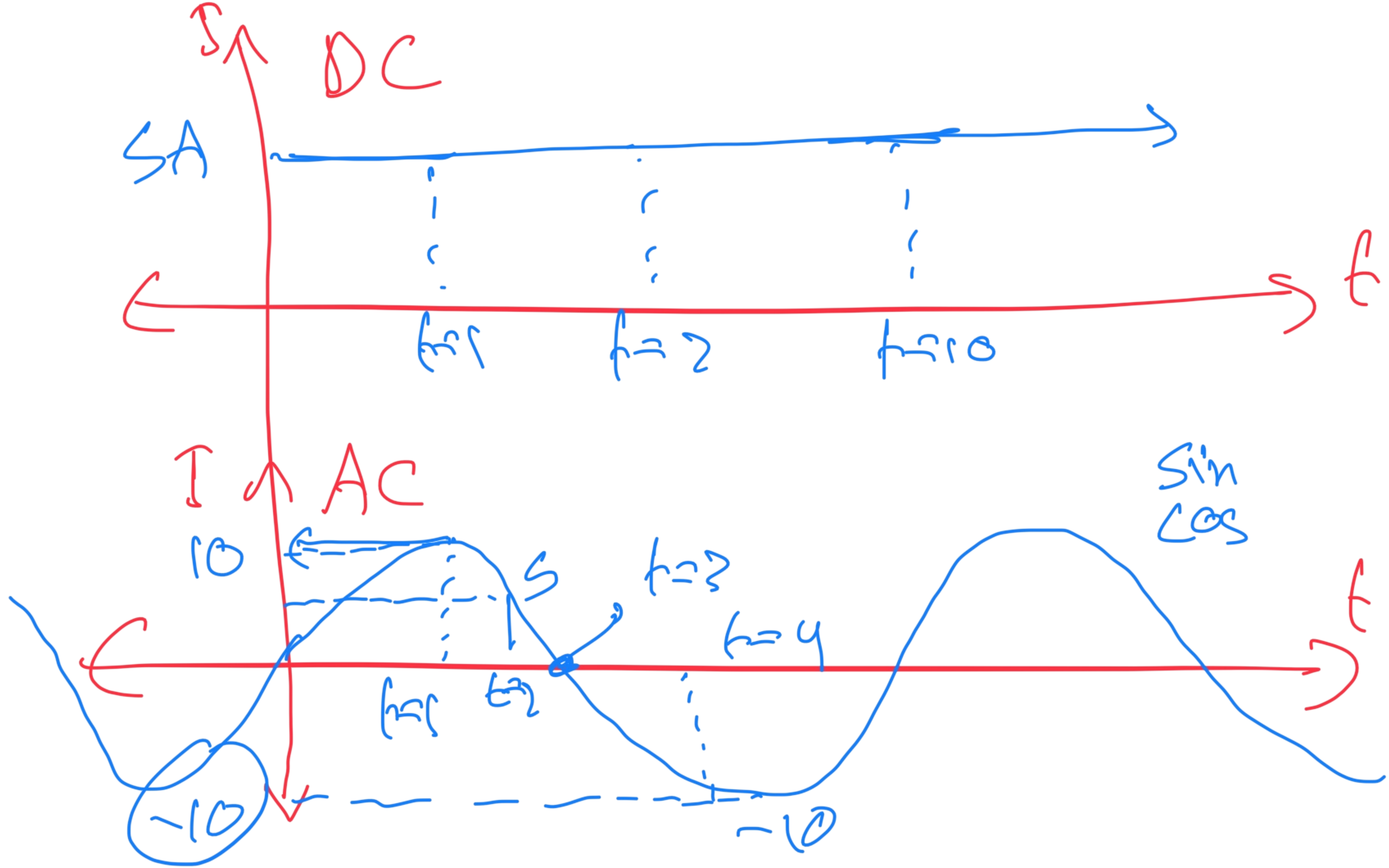
The flow of electric charge can occur in two main types. ثابت الاتجاه

1- **Direct current (DC),** where the charge flows consistently in one direction, → DC

2- **Alternating current (AC)**, where the charge periodically reverses direction. → AC

Circuits 2

تغير الاتجاه والقيمة


I
DC
5A
t
t=1
t=2
t=10
I
AC
10
5
t=3
t=4
t=1
t=2
-10
-10
sin
cos
t

2- Circuit variables

c) Power (P)

Definition: the power is the rate of energy consumption or production per unit time,

Symbol: P

Unit: $\boxed{\text{Watt (W)}}$

Formula: $P = \frac{dW}{dt}$, P: the power in Watt, W: the energy in Joule, t: the time in second

$$P = \frac{dW}{dt} = \frac{dW}{dq} * \frac{dq}{dt} = \boxed{V*I}$$

$$\mathbf{1\ W = \boxed{1J/s}}$$

$P = Vi$

2- Circuit variables

d) Energy (E)

Definition: energy refers to the capacity to do work through the movement of electric charge,

Symbol: E

$\boxed{\textbf{Unit: } \text{Joule (J)}}$

J / second

Formula: **W** = $P * t$, E: the energy in Joule, P: the power in Watt, t: the time in second

$$\frac{J}{\cancel{S}} \cdot \cancel{S} = J$$

2- Circuit variables

اشارة ال power تحدد

Passive sign convention

Current direction and voltage polarity play a major role in determining the sign of power.

Whenever the reference direction for the current in an element is in the direction of the reference voltage drop across the element (as in Fig. 1.5), use a positive sign in any expression that relates the voltage to the current. Otherwise, use a negative sign.

◀ Passive sign convention

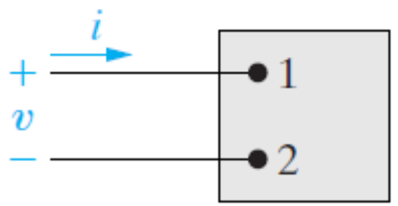


Figure 1.5 ▲ An ideal basic circuit element.

قطبية polarity

أنواع الأدوات :

الـ

نوع يعطي power

نوع يأخذ power

⟸ مبدأ حفظ الطاقة

[1] $P = \boxed{+}VI$ → absorbed. dissipated مستهلك

P = power أخذ ال ⇐

V, I ال "أحيانًا"

[2] $P = \boxed{-}VI$ → supplying معطي

power يعطي ⇐

"غالبًا" ال جهد أو تيار.

2- Circuit variables

Passive sign convention

Current direction and voltage polarity play a major role in determining the sign of power.

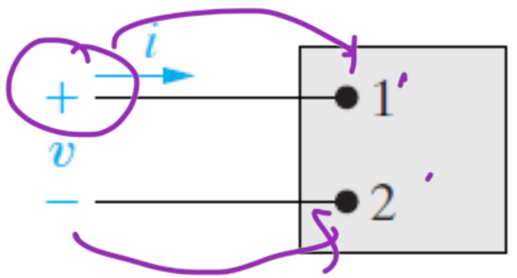


Figure 1.5 ▲ An ideal basic circuit element.

TABLE 1.4 Interpretation of Reference Directions in Fig. 1.5

	Positive Value	Negative Value
v	voltage drop from terminal 1 to terminal 2 *or* voltage rise from terminal 2 to terminal 1	voltage rise from terminal 1 to terminal 2 *or* voltage drop from terminal 2 to terminal 1
i	positive charge flowing from terminal 1 to terminal 2 *or* negative charge flowing from terminal 2 to terminal 1	positive charge flowing from terminal 2 to terminal 1 *or* negative charge flowing from terminal 1 to terminal 2

2- Circuit variables

Passive sign convention

Current direction and voltage polarity play a major role in determining the sign of power.

By the passive sign convention, current enters through the positive polarity of voltage.

(a)absorbing ; (b) supplying

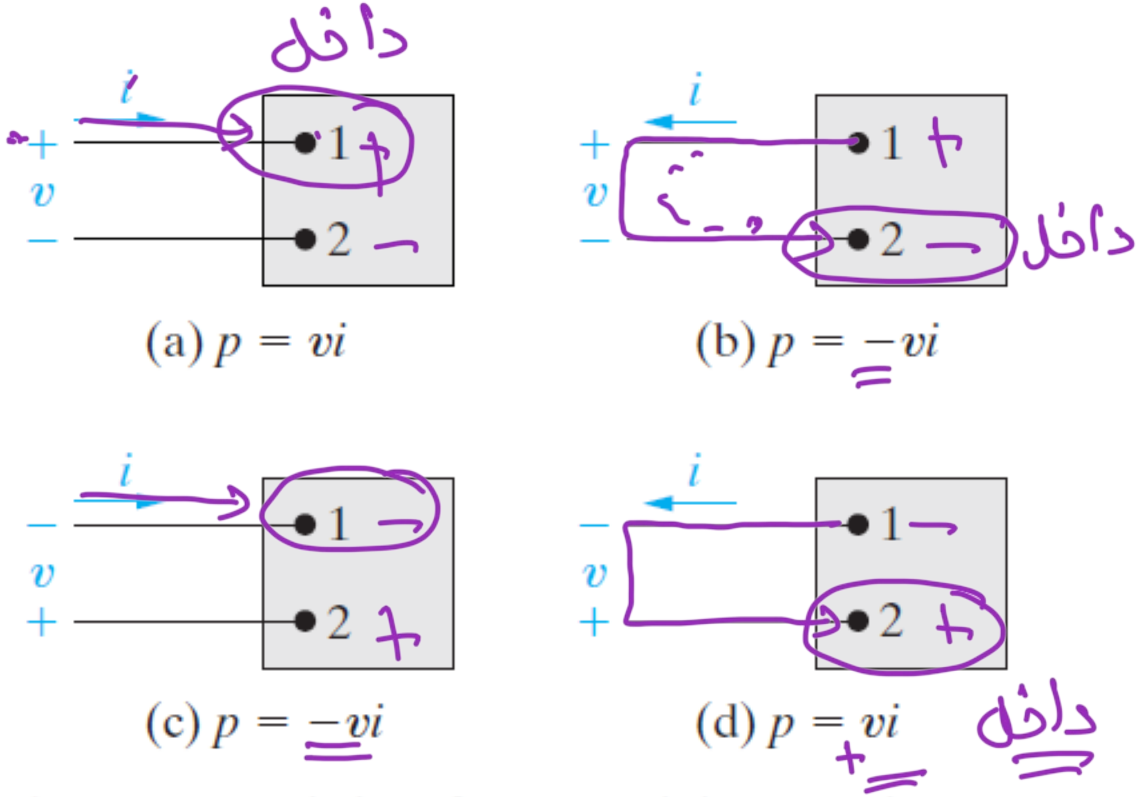


Figure 1.6 ▲ Polarity references and the expression for power.

If the power is positive (that is, if $p > 0$), power is being delivered to the circuit inside the box. If the power is negative (that is, if $p < 0$), power is being extracted from the circuit inside the box.

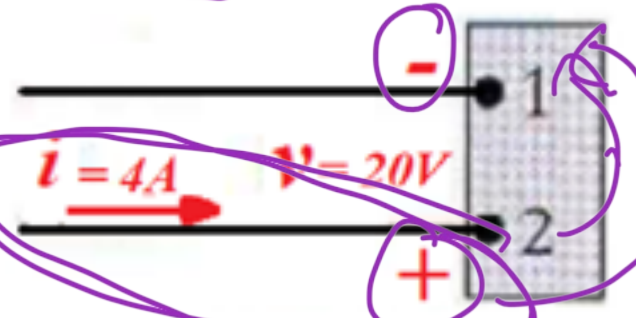
Example 1 (problem 1.5)

Assume that a 20 V voltage drop occurs across an element from terminal 2 to terminal 1 and that the current of 4 A enters terminal 2.

a) Specify the values of *v* and *i* for the polarity references shown below.

b)How much power is the circuit absorbing?

b)State whether the circuit inside the box is absorbing or delivering power.



a)

b) $p = +vi = 4 \times 20 = 80\,W$

c) $p\ (+) \Rightarrow$ absorbing power

عند عكس اتجاه التيار تتغير اشارته فقط

$\longrightarrow i$

$-i \quad \longleftarrow$

عند عكس القطبية تتغير الاشارة فقط

$$SV \quad \left.\begin{matrix} + \\ - \end{matrix}\right\} \Rightarrow \begin{matrix} - \\ + \end{matrix} \; -SV$$

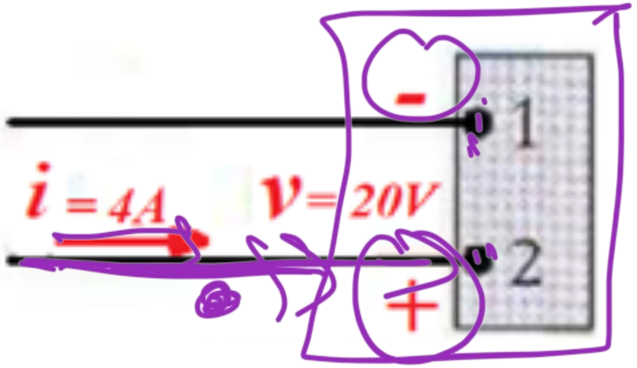
2- Circuit variables

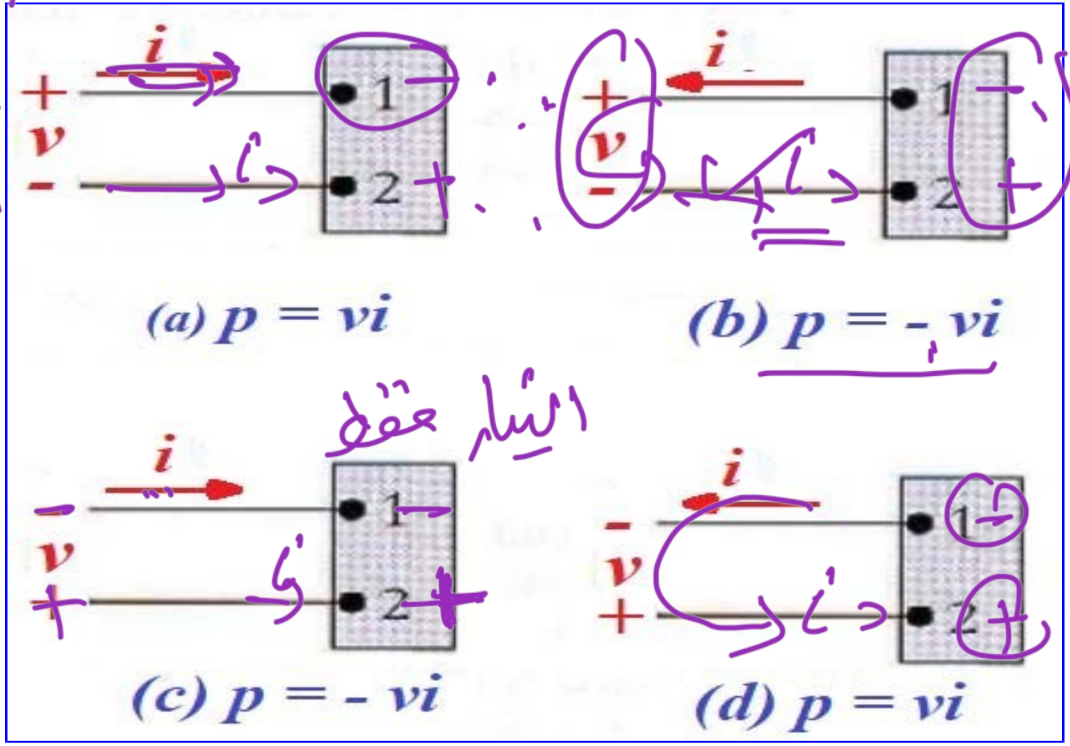
Solution

a)
-voltage drop of 20 V from terminal 2 to terminal 1
-current of 4 A enters terminal 2 Circuit
(a): ***v* = -20*V*** and ***i* = - 4*A***
Circuit (b): ***v* = -20*V*** and ***i* = 4*A***
Circuit (c): ***v* = 20*V*** and ***i* = - 4*A***
Circuit (d): ***v* = 20*V*** and ***i* = 4*A***

b)
$p = v\,i$ = (-20)x(-4) = 80 W for (a).
$p = -v\,i$ = -(-20)x(4) = 80 W for (b).
$p = -v\,i$ = -(20)x(-4) = 80 W for (c).
$p = v\,i$ = (20)x(4) = 80 W for (d).

c)
$p > 0$ so, the box is absorbing power





$i = 4A \qquad V = 20V$

a) $P = +Vi \Rightarrow P = (-4)(-20) = 80W$

b) $P = -Vi \Rightarrow P = -(4)(-20) = 80W$

c) $P = -Vi \Rightarrow P = -(-4)(20) = 80W$

d) $P = +Vi \Rightarrow P = +(4)(20) = 80W$

Example 2:Problem 1 in HW

The numerical values for the currents and voltages in the circuit in Fig. P1.29 are given in Table P1.29. Find the total power developed in the circuit.

TABLE P1.29

Element	Voltage (V)	Current (mA)
a	40	−4
b	−24	−4
c	−16	4
d	−80	−1.5
e	40	2.5
f	120	−2.5

$\to 10^{-3}$

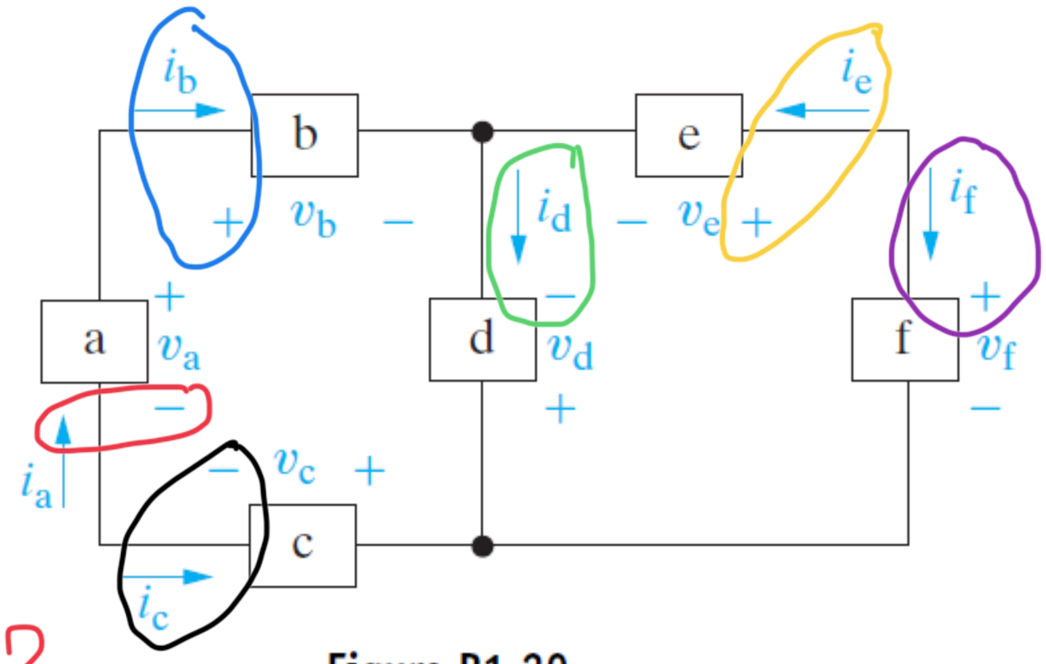


Figure P1.29

داخلا للسهولة تعاملو
مع الداخل

$$P_a = -i_a v_a = -(-4m)*40 = +160\,mW$$

$$P_b = +i_b v_b = +(-4m)(-24) = +96\,mW$$

$$P_c = -i_c v_c = -(4m)(-16) = +64\,mW$$

$$P_d = -i_d v_d = +(+1.5m)(-80) = -120\,mW$$

$$P_e = +i_e v_e = +(2.5m)(40) = +100\,mW$$

$$P_f = +i_f v_f = +(-2.5m)(120) = -300\,mW$$

$$\Rightarrow \sum P_{+} = 160 + 96 + 64 + 100 = 420\,mW$$

absorbing

$$\Rightarrow \sum P_{-} = -120 + -300 = -420\,mW$$

dev

$$\sum P_{abs} = \sum P_{dev}$$

امتصاص = إنتاج

$$\Rightarrow \boxed{\sum P = 0} \Rightarrow$$ valid صحيح

Solution

We use the passive sign convention to determine whether the power equation is $p = vi$ or $p = -vi$ and substitute into the power equation the values for v and i, as shown below:

$$
\begin{aligned}
p_{\mathrm{a}} &= -v_{\mathrm{a}} i_{\mathrm{a}} = -(40)(-4 \times 10^{-3}) = 160 \text{ mW} \\
p_{\mathrm{b}} &= v_{\mathrm{b}} i_{\mathrm{b}} = (-24)(-4 \times 10^{-3}) = 96 \text{ mW} \\
p_{\mathrm{c}} &= -v_{\mathrm{c}} i_{\mathrm{c}} = -(-16)(4 \times 10^{-3}) = 64 \text{ mW} \\
p_{\mathrm{d}} &= -v_{\mathrm{d}} i_{\mathrm{d}} = -(-80)(-1.5 \times 10^{-3}) = -120 \text{ mW} \\
p_{\mathrm{e}} &= v_{\mathrm{e}} i_{\mathrm{e}} = (40)(2.5 \times 10^{-3}) = 100 \text{ mW} \\
p_{\mathrm{f}} &= v_{\mathrm{f}} i_{\mathrm{f}} = (120)(-2.5 \times 10^{-3}) = -300 \text{ mW}
\end{aligned}
$$

We can add the positive powers together and the negative powers together — if the power balances, these power sums should be equal:

$\sum P_{\mathrm{dev}} = 120 + 300 = 420$ mW;

$\sum P_{\mathrm{abs}} = 160 + 96 + 64 + 100 = 420$ mW

Thus, the power balances and the total power absorbed in the circuit is 420 mW.

Lect: 2

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Electric Circuits I

Chapter 2: Circuit Elements

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Chapter 2: Basic Concepts of Electric Circuits
Part 2: Circuit Elements

Introduction

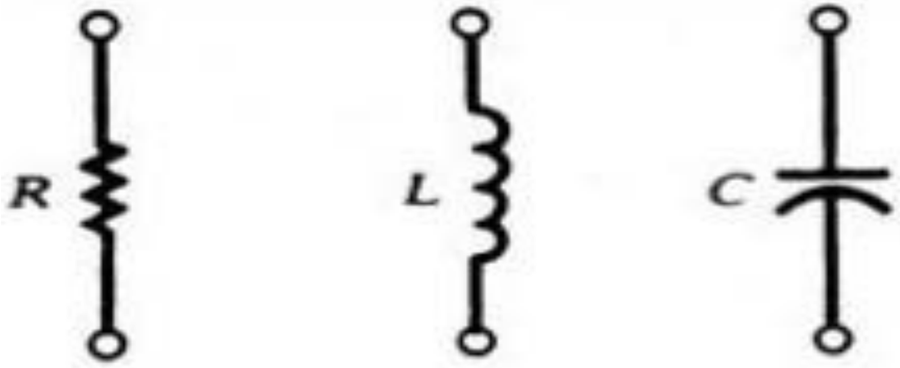
There are two types of elements found in electric circuits: passive elements and active elements.

- An **active element** is capable of generating energy
  Example: **batteries, generators and operational amplifiers,**
- A **passive element** is not.
  Example: **resistors, capacitors and inductors**

The most important active elements are **voltage or current sources** that generally deliver power to the circuit connected to them,

There are two types of sources: **independent and dependent sources**

a) Passive elements



Resistance **Inductance** **Capacitor**

b) Active elements

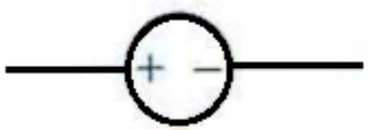
- ✓ Independent sources
- ✓ Dependent sources

Independent voltage and current sources

1) Independent sources

- Ideal independent voltage source is a circuit that maintains prescribed voltage across its terminals regardless of the current flowing in those terminals

- Ideal independent current source is a circuit that maintains prescribed current through its terminals regardless of the voltage across those terminals.



V

Ideal independent voltage source

I

Ideal independent current source

Dependent voltage and current sources

Dependent sources

The dependent source establishes a voltage or a current in the circuit whose value depends on the value of voltage or current elsewhere in the circuit.

(a) voltage-controlled voltage source

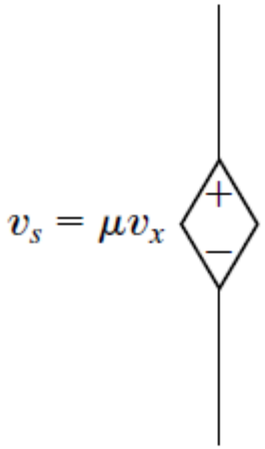
μ: is a multiplying constant dimensionless

Vx: controlling voltage

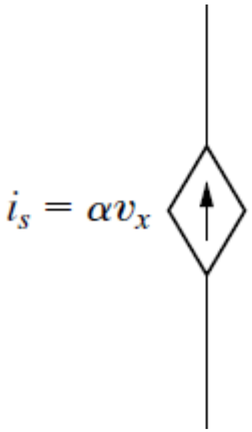
(b) current-controlled voltage source

ρ: is a multiplying constant V/A

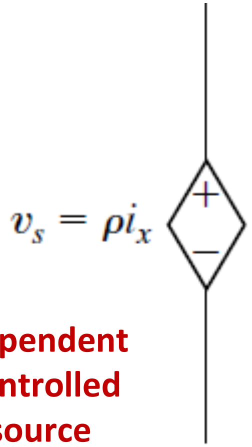
ix: controlling current



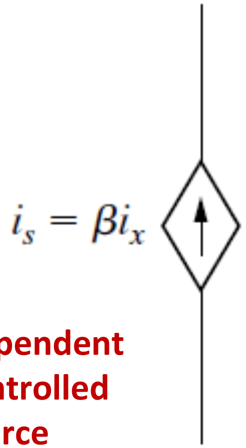
an ideal dependent voltage-controlled voltage source



An ideal dependent voltage-controlled current source



an ideal dependent current-controlled voltage source



an ideal dependent current-controlled current source

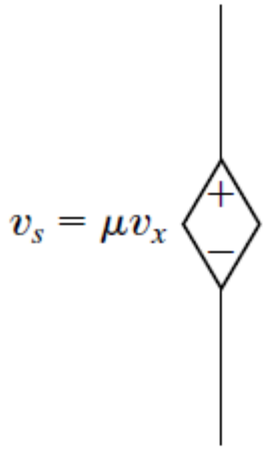
- ## Dependent voltage and current sources

Dependent sources

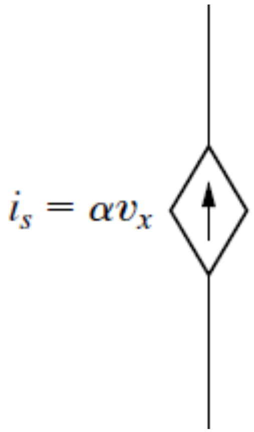
The dependent source establishes a voltage or a current in the circuit whose value depends on the value of voltage or current elsewhere in the circuit

(c) voltage-controlled current source
α: is a multiplying constant A/V
Vx: controlling voltage

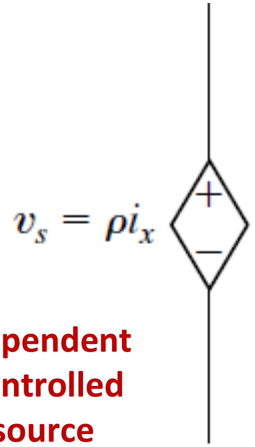
(c) current-controlled current source
β: is a multiplying dimensionless
ix: controlling current



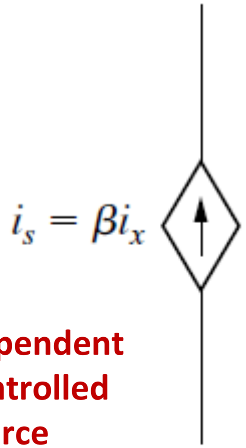
an ideal dependent voltage-controlled voltage source



An ideal dependent voltage-controlled current source



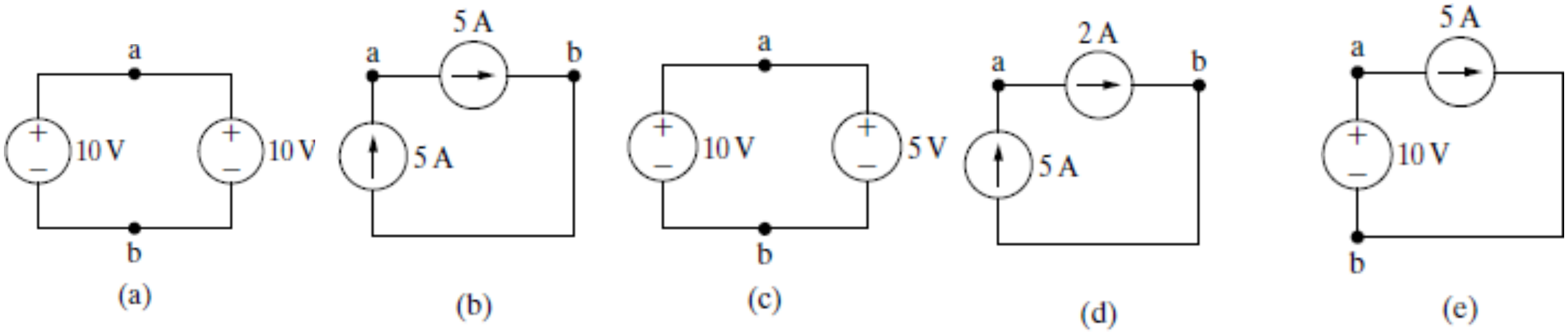
an ideal dependent current-controlled voltage source



an ideal dependent current-controlled current source

Interconnections of independent sources

Problem 2.1: Using the definitions of ideal independent voltage and current sources, the following connections may be valid or invalid or not permissible,



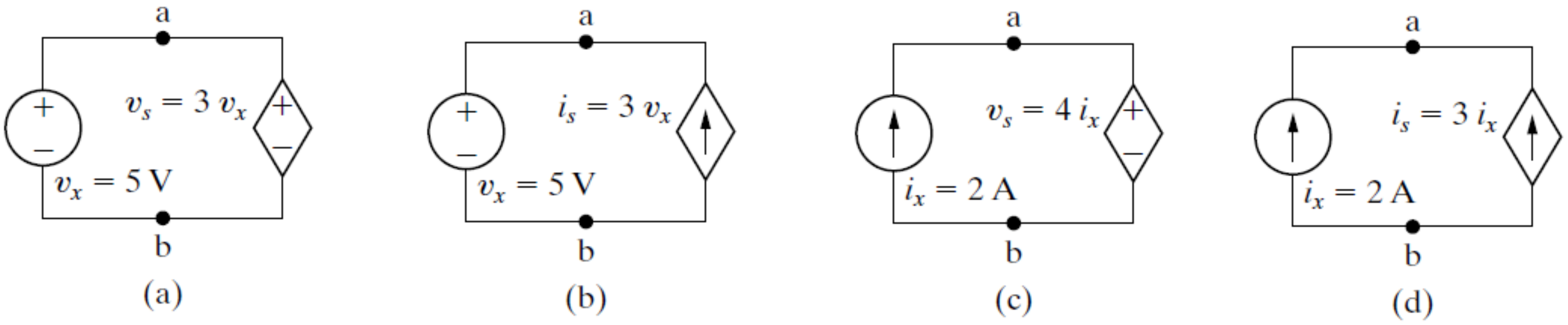
Connection (a) is valid.
Connection (b) is valid.

Connection (c) is not permissible.
Connection (d) is not permissible.

Connection (e) is valid.

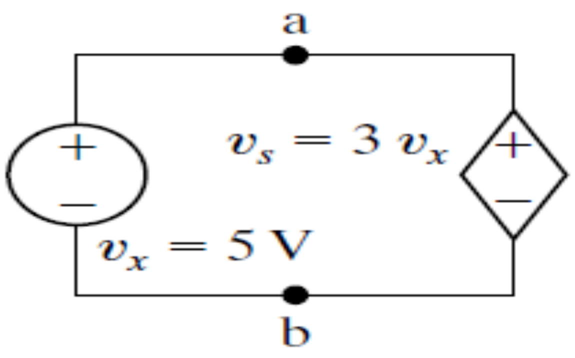
Interconnections of dependent and independent sources

Problem 2.2: Using the definitions of ideal independent and dependent sources, in the following some connections are valid and some others are invalid,

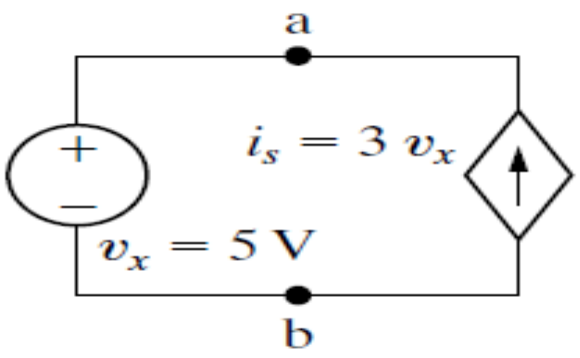


Interconnections of dependent and independent sources

Problem 2.2: answer



(a)



(b)

(a): invalid.

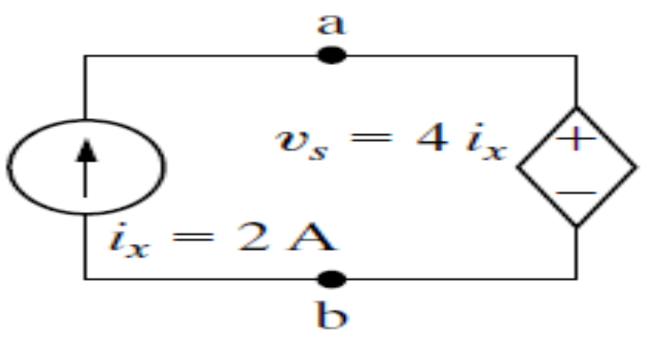
Reason: The independent voltage source supplies 5 V and the dependent voltage source supplies 15 V although they supply voltage across the same pair of terminals a, b.

(b): valid.

Reason: An ideal voltage source supplies the same voltage regardless of current, and an ideal current source supplies the same current regardless of voltage.

Interconnections of dependent and independent sources

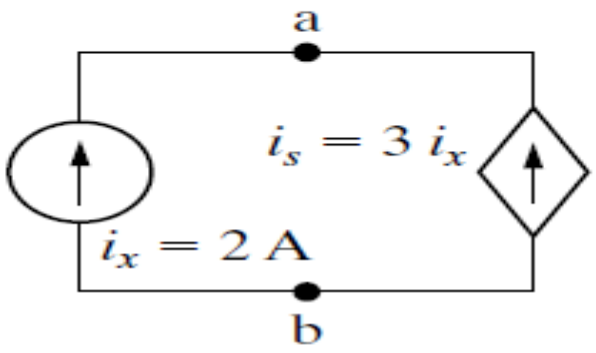
Problem 2.2: answer



(c)

(c): valid.

Reason: An ideal voltage source supplies the same voltage regardless of current, and an ideal current source supplies the same current regardless of voltage.



(d)

(d): invalid.

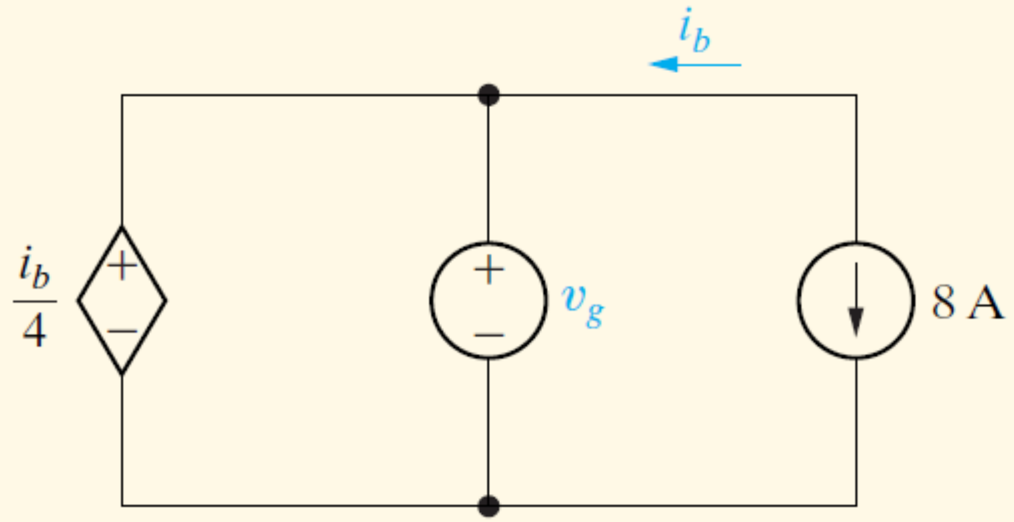
Reason: The independent source supplies 2 A and the dependent source supplies 6 A although they supply current through the same pair of terminals a, b.

Example 3

For the circuit shown,

a) What value of v_g is required in order for the interconnection to be valid?

b) For this value of v_g, find the power associated with the 8 A source.



Solution

a) $V_g = i_b/4 = -8/4 = -2$ V,

b) $P_{8A} = +V_g \times 8 = -2\times 8 = -16$ W (delivered)

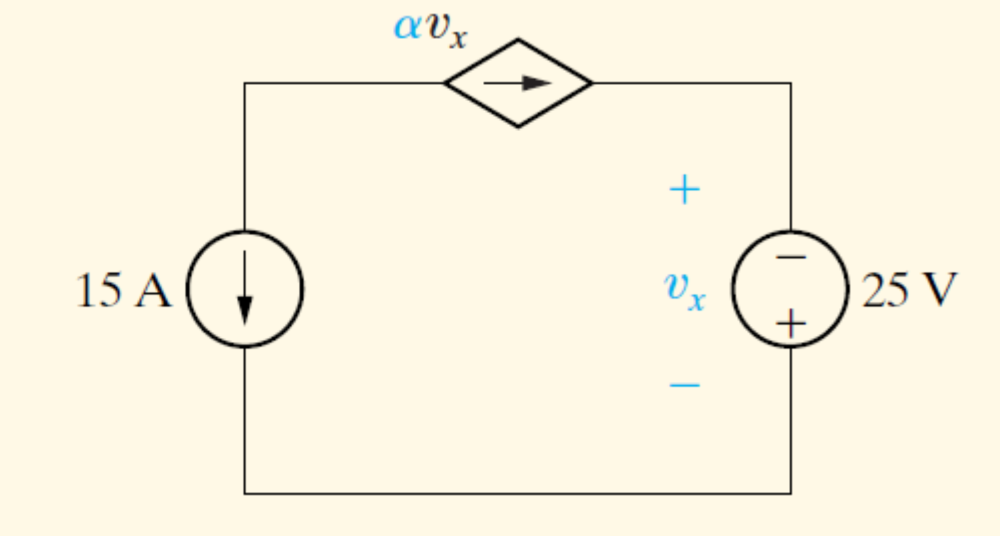
Answer: (a) −2 V;
(b) −16 W (16 W delivered)

Example 4

For the circuit shown,

a) What value of α is required in order for the interconnection to be valid?

b) For the value of α calculated in part (a), find the power associated with the 25 V source.



Solution

a) Vx = -25,
α.Vx = -15,
α = -15/Vx
α = -15/(-25)
α = 0.6 A/V
b) P_{25V} = 25x15 =+375W (absorbed)

2-3 Electrical Resistance (Ohm's Law)

For purpose of circuit analysis, we must reference the current in the resistor to the terminal voltage as shown in the following figures:

If we choose the first figure, the relationship between the voltage and current is:

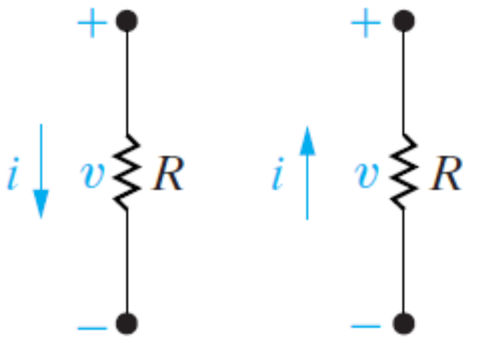
Ohm's law ▶

$$\boxed{v = iR,}$$

v = the voltage in volts,

i = the current in amperes,

R = the resistance in ohms.



$v = iR$ $\qquad$ $v = -iR$

Figure 2.6 ▲ Two possible reference choices for the current and voltage at the terminals of a resistor, and the resulting equations.

2-3 Electrical Resistance (Ohm's Law)

Ohm's law is the algebraic relationship between voltage and current for a resistor. In SI units, resistance is measured in ohms. The Greek letter omega (Ω) is the standard symbol for an ohm.

Ohm's law expresses the voltage as a function of the current. However, from Eq. 2.1, expressing the current as a function of the voltage also is convenient. Thus,

$$\boxed{i = \frac{v}{R},}$$

$$\boxed{i = -\frac{v}{R}.}$$

The reciprocal of the resistance is referred to as **conductance**, is symbolized by the letter G, and is measured in siemens (S). Thus,

$$\boxed{G = \frac{1}{R}\ \text{S}}$$

2-3 Electrical Resistance (Ohm's Law)

Power in resistance

We may calculate the power at the terminals of a resistor in several ways. The first approach is to use the defining equation and simply calculate the product of the terminal voltage and current.

$$p = vi \quad \rightarrow \quad p = vi = (i\,R)i$$

Power in a resistor in terms of current ▶ $$p = i^2 R.$$

Power in a resistor in terms of voltage ▶ $$p = \frac{v^2}{R}.$$

$$\boxed{p = \frac{i^2}{G}, \qquad p = v^2 G.}$$

Example 2.3 Calculating Voltage, Current, and Power for a Simple Resistive Circuit

In each circuit in Fig. 2.8, either the value of v or i is not known.

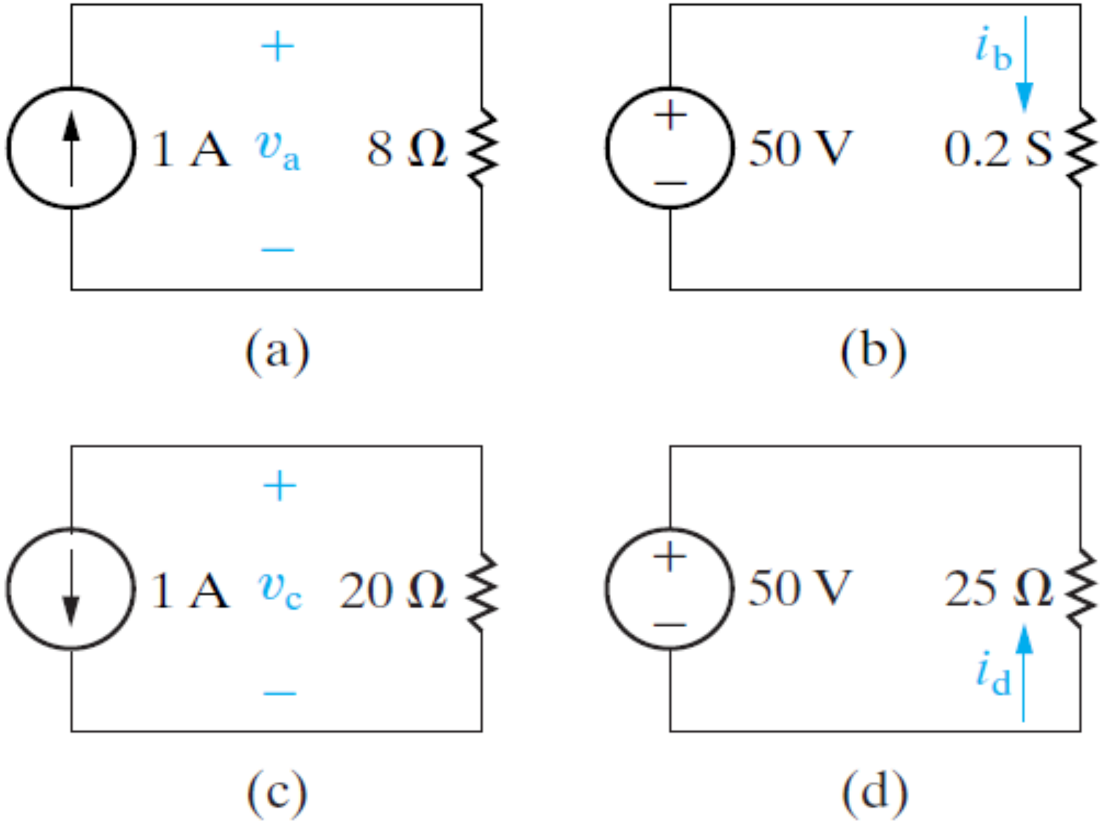
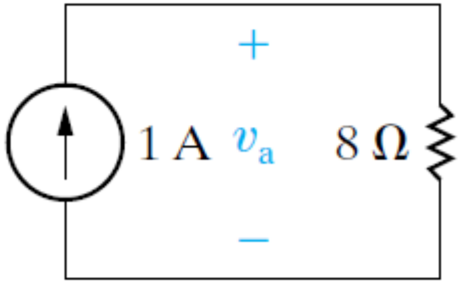


Figure 2.8 ▲ The circuits for Example 2.3.

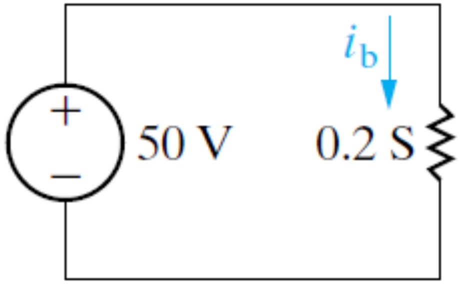
a) Calculate the values of V and i.

b) Determine the power dissipated in each resistor

Solution



(a)



(b)

a) The voltage v_a in Fig. 2.8(a) is a drop in the direction of the current in the resistor. Therefore,

$$v_a = (1)(8) = 8 \text{ V}.$$

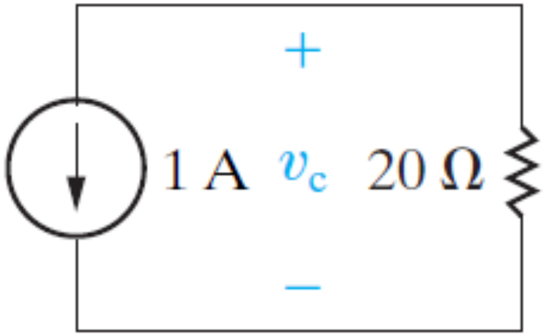
$$p_{8\Omega} = \frac{(8)^2}{8} = (1)^2(8) = 8 \text{ W},$$

The current i_b in the resistor with a conductance of 0.2 S in Fig. 2.8(b) is in the direction of the voltage drop across the resistor. Thus

$$i_b = (50)(0.2) = 10 \text{ A}.$$

$$p_{0.2S} = (50)^2(0.2) = 500 \text{ W},$$

Solution

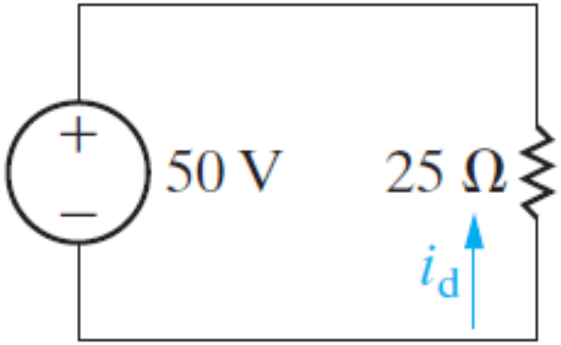


(c)

The voltage v_c in Fig. 2.8(c) is a rise in the direction of the current in the resistor. Hence

$$v_c = -(1)(20) = -20 \text{ V}.$$

$$p_{20\Omega} = \frac{(-20)^2}{20} = (1)^2(20) = 20 \text{ W},$$



(d)

The current i_d in the 25 Ω resistor in Fig. 2.8(d) is in the direction of the voltage rise across the resistor. Therefore

$$i_d = \frac{-50}{25} = -2 \text{ A}.$$

$$p_{25\Omega} = \frac{(50)^2}{25} = (-2)^2(25) = 100 \text{ W}$$

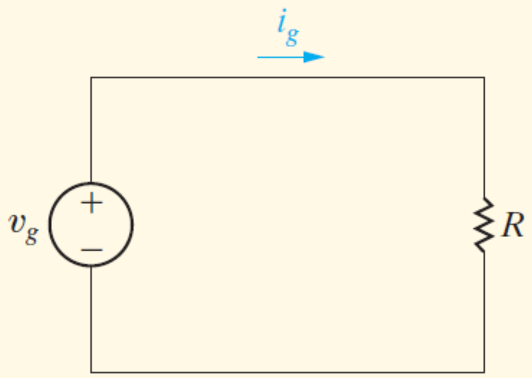
Example 4 (problem2.3)

For the circuit shown,

a) If $v_g = 1$ kV and $i_g = 5$ mA, find the value of R and the power absorbed by the resistor.

b) If $i_g = 75$ mA and the power delivered by the voltage source is 3 W, find v_g, R, and the power absorbed by the resistor.

c) If $R = 300\ \Omega$ and the power absorbed by R is 480 mW, find i_g and v_g.



Answer: (a) 200 kΩ, 5 W;
(b) 40 V, 533.33 Ω, 3 W;
(c) 40 mA, 12 V.

Example 4 (problem2.3)

For the circuit shown,

a) If $v_g = 1$ kV and $i_g = 5$ mA, find the value of R and the power absorbed by the resistor.

b) If $i_g = 75$ mA and the power delivered by the voltage source is 3 W, find v_g, R, and the power absorbed by the resistor.

c) If $R = 300\ \Omega$ and the power absorbed by R is 480 mW, find i_g and v_g.

Solution

a) $V_g = i_g R$, $R = V_g/i_g = 1000/0.005 = \underline{200\ k\Omega}$

$P = (ig)^2.R = (0.005)^2 x 2x10^5 = \underline{5W}$

b) $P_G = V_g.i_g$, $V_g = P_G / i_g$

$V_g = 3/0.075 = \underline{40\ V}$

$R = V_g/i_g = 40/0.075 = 533.33\ \Omega$

$P = (ig)^2.R = (0.075)^2 x533.33 = 3W$

c) $P = (ig)^2.R$ $i_g = \underline{40\ mA}$

So, $i_g = (P_G/R)^{1/2} = (0,48/300)^{1/2}$

$V_g = i_g R = 0.04x300 = 12\ V$

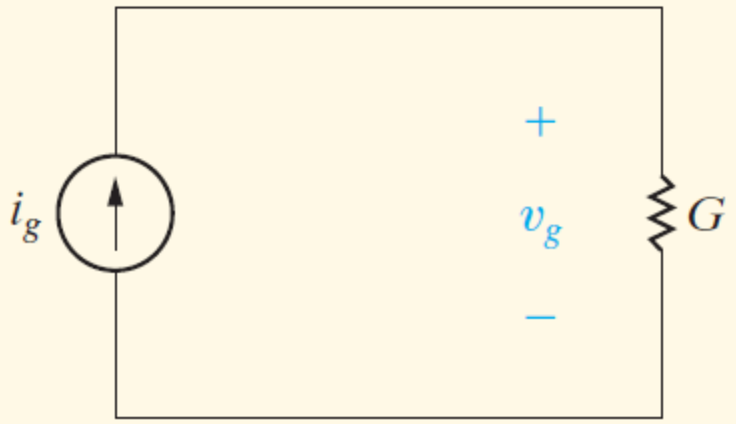
Example 4 (problem2.4)

For the circuit shown,

a) If $i_g = 0.5$ A and $G = 50$ mS, find v_g and the power delivered by the current source.

b) If $v_g = 15$ V and the power delivered to the conductor is 9 W, find the conductance G and the source current i_g.

c) If $G = 200\ \mu$S and the power delivered to the conductance is 8 W, find i_g and v_g.



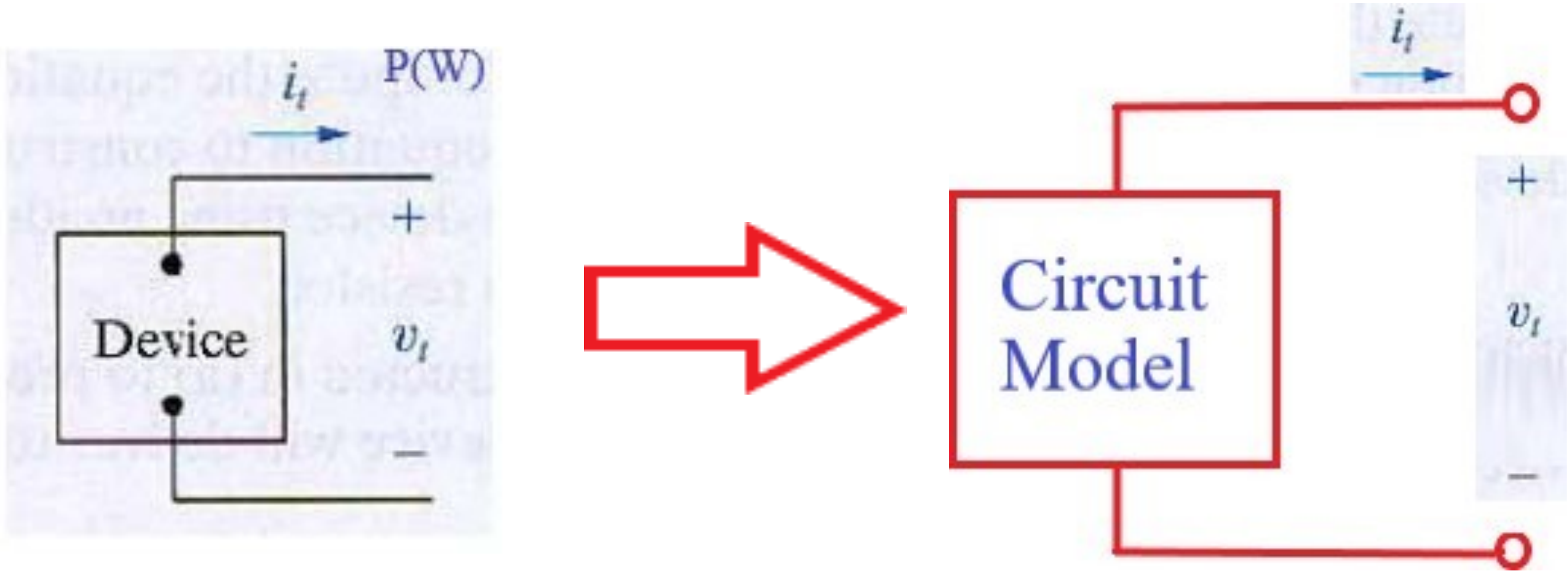
Answer: (a) 10 V, 5 W;
(b) 40 mS, 0.6 A;
(c) 40 mA, 200 V.

Class activity

2-4 Construction of a circuit model

- One reason for an interest in the basic circuit elements is that they can be used to construct circuit models of practical systems.

- The construction of a circuit model based on a knowledge of the behavior of the system's components and how the components are interconnection



2-4 Construction of a circuit model

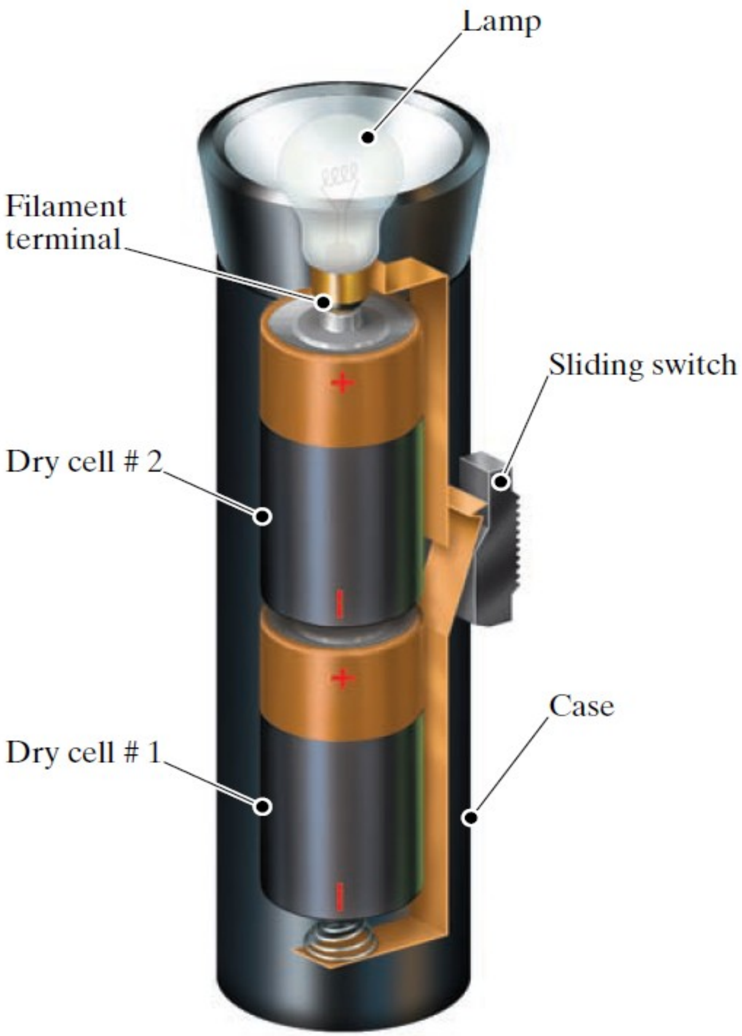


Figure 2.11 ▲ The arrangement of flashlight components.

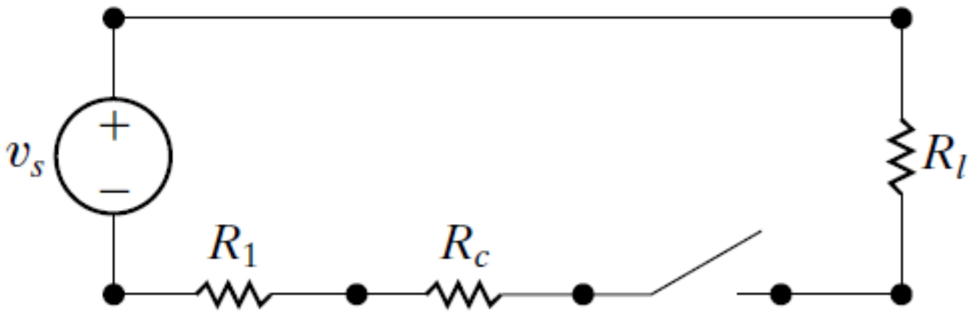
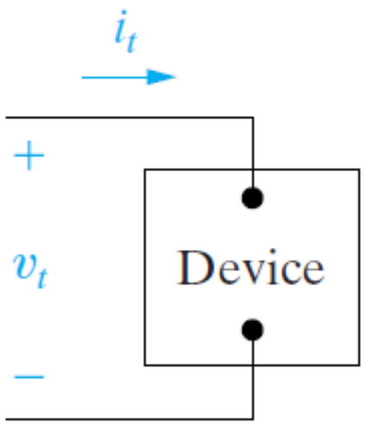


Figure 2.12 ▲ A circuit model for a flashlight.

Example 2.5 Constructing a Circuit Model Based on Terminal Measurements

The voltage and current are measured at the terminals of the device illustrated in Fig. 2.13(a), and the values of v_t and i_t are tabulated in Fig. 2.13(b). Construct a circuit model of the device inside the box.



(a)

v_t (V)	i_t (A)
−40	−10
−20	−5
0	0
20	5
40	10

(b)

Figure 2.13 ▲ The (a) device and (b) data for Example 2.5.

Example 2.5 Constructing a Circuit Model Based on Terminal Measurements

Solution

Plotting the voltage as a function of the current yields the graph shown in Fig. 2.14(a). The equation of the line in this figure illustrates that the terminal voltage is directly proportional to the terminal current, $v_t = 4i_t$. In terms of Ohm's law, the device inside the box behaves like a 4 Ω resistor. Therefore, the circuit model for the device inside the box is a 4 Ω resistor, as seen in Fig. 2.14(b).

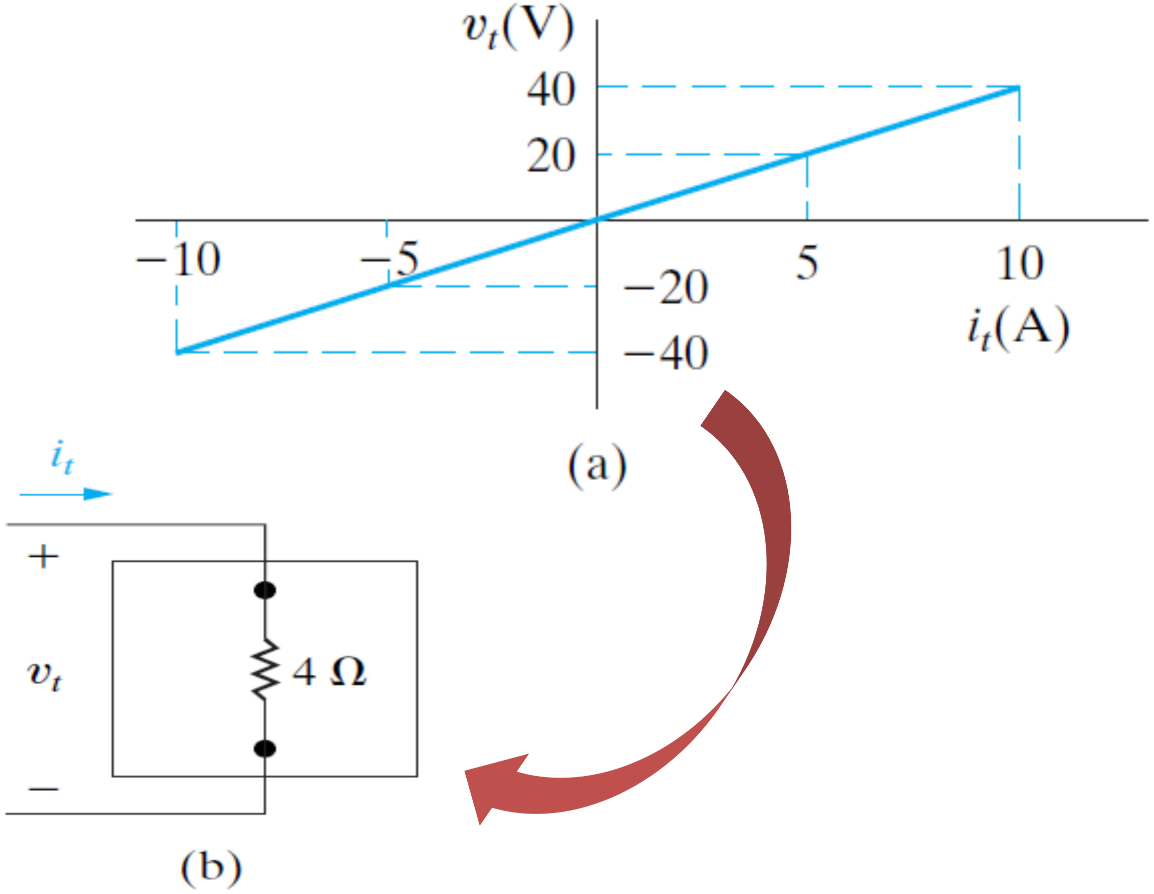


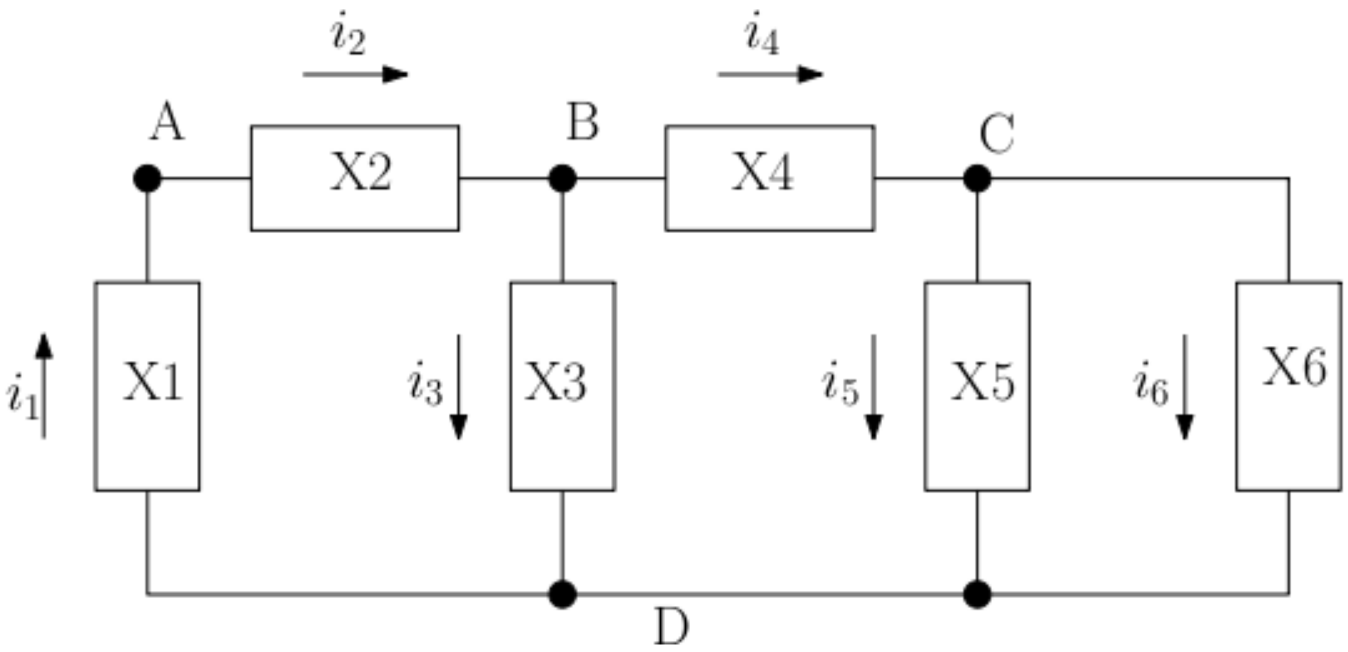
Figure 2.14 ▲ (a) The values of v_t versus i_t for the device in Fig. 2.13. (b) The circuit model for the device in Fig. 2.13.

2-5 Kirchhoff’s Laws

- **Node**

The node is a point where two or three or more circuit elements meet. It is necessary to identify nodes in order to use **Kirchhoff’s Current Law (KCL)**.

In the circuit shown ,the nodes are labeled : A, B, C, D

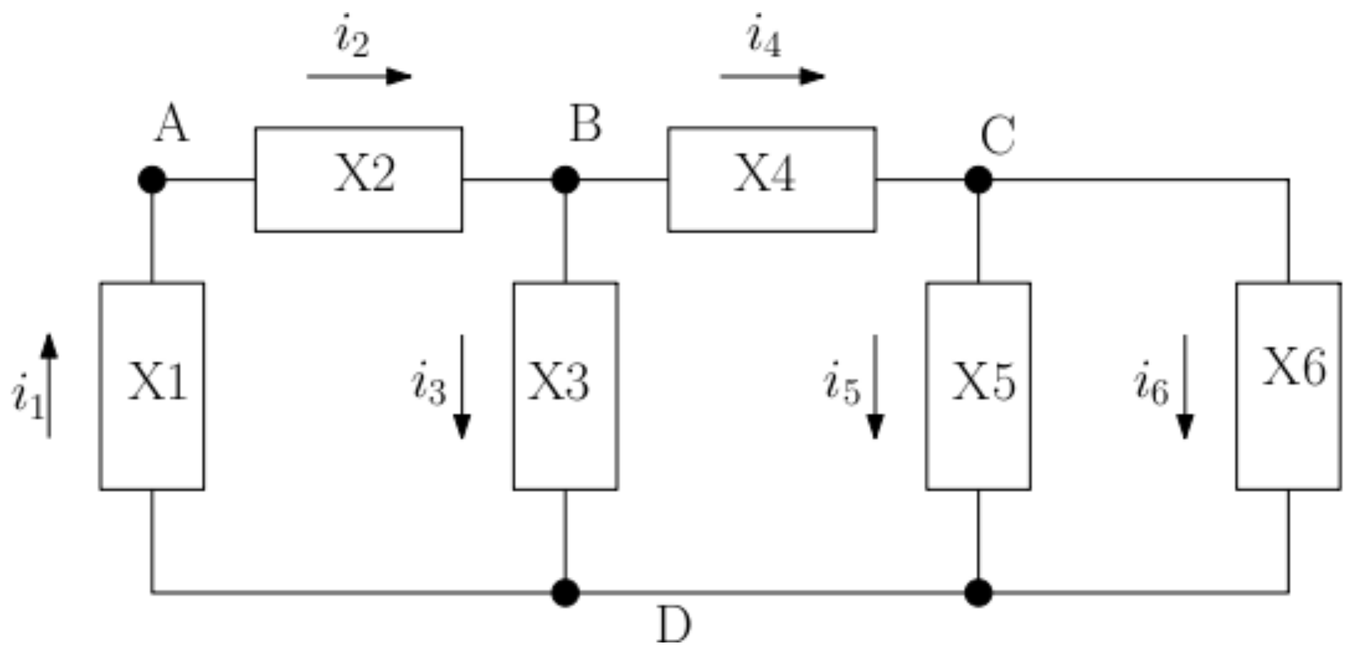


2-5 Kirchhoff’s Laws

- **Branches**

A circuit is visualized as a network in which each element constitute a branch.

The network shows in the figure has 6 branches labeled: X1, X2, X3, X4, X5, X6



2-5 Kirchhoff's Laws

- ## Loops

we trace a closed path in a circuit through selected basic circuit elements and return to the original node without passing through any intermediate node more than once.

In the circuit shown in the figure, There are 6 Loops:

Loop (1): X1 X2 X3

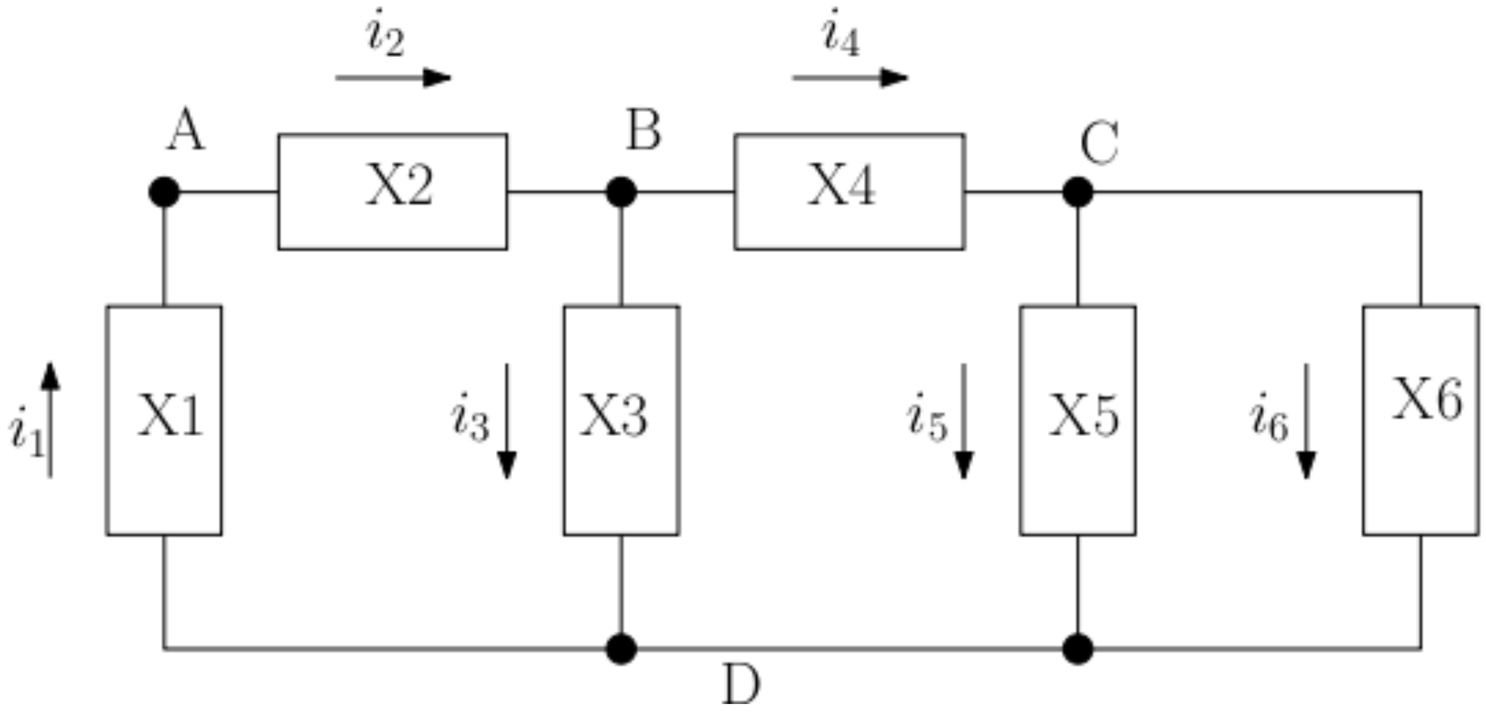
Loop (2): X3 X4 X5

Loop (3): X5 X6

Loop (4): X1 X2 X4 X5

Loop (5): X1 X2 X4 X6

Loop (6): X3 X4 X6



2-5 Kirchhoff's Laws

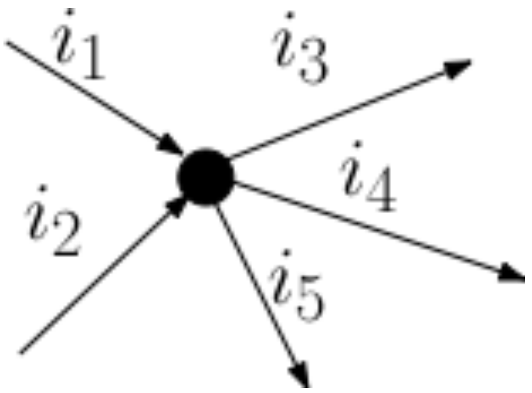
a) KCL: Kirchhoff's Curent Law

The algebraic sum of all the currents at any node in a circuit equals zero.

$$\sum i_{out} - \sum i_{in} = 0$$

Or

$$\sum i_{in} = \sum i_{out}$$

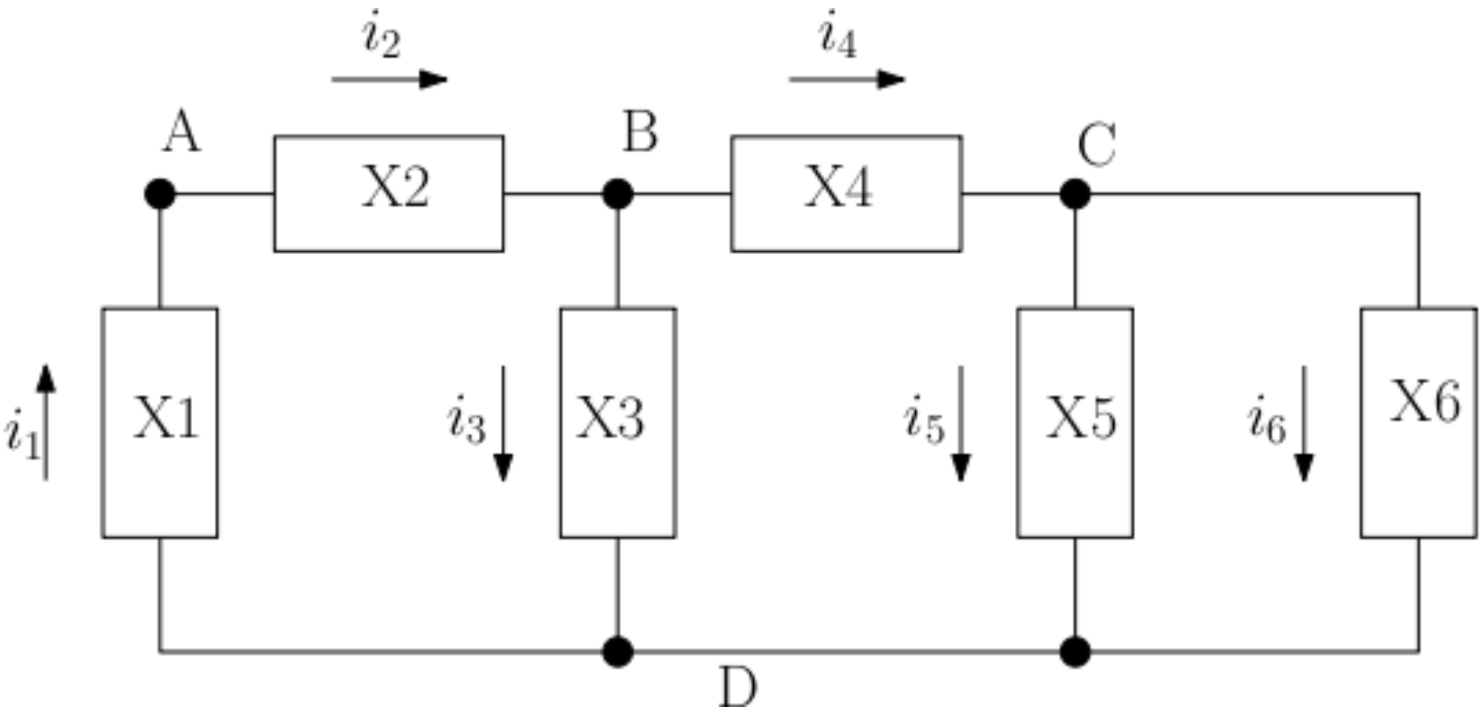


$$i_1 + i_2 = i_3 + i_4 + i_5$$

2-5 Kirchhoff's Laws

Example 5:

Apply KCL to the circuit shown in the figure



At Node A :

$$i_1 = i_2$$

At Node B :

$$i_2 = i_3 + i_4$$

At Node C :

$$i_4 = i_5 + i_6$$

At Node D :

$$i_1 = i_3 + i_5 + i_6$$

2-5 Kirchhoff's Laws

b) KVL: Kirchhoff's Voltage Law

The algebraic sum of all the voltages around any closed path in a circuit equals zero.

$$\sum v_{rise} - \sum v_{drop} = 0$$

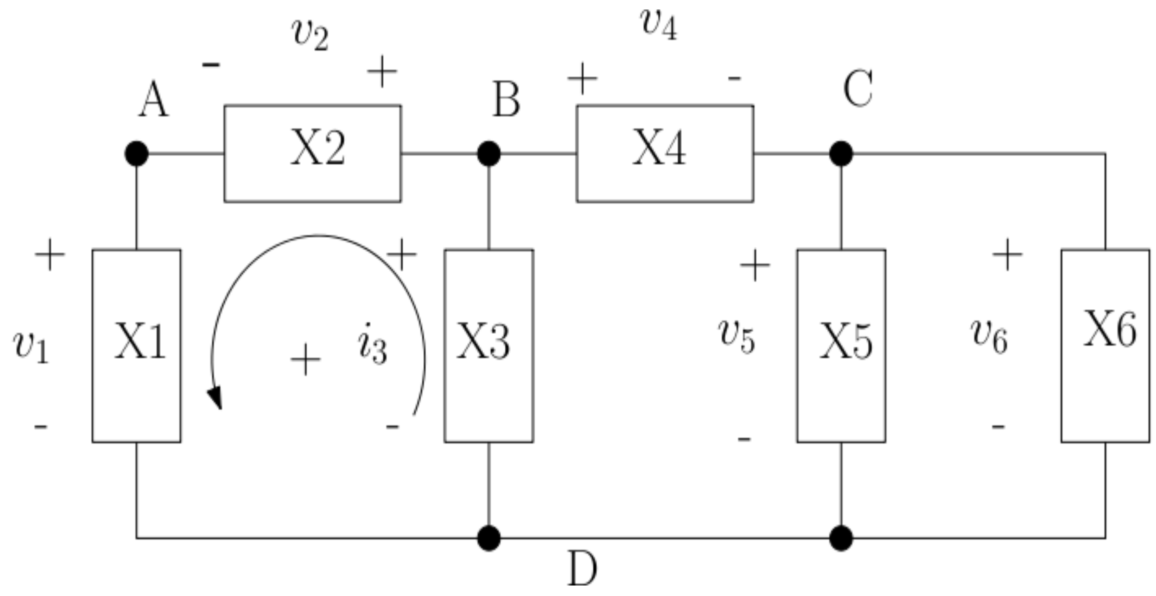
Or

$$\sum v_{rise} = \sum v_{drop}$$

Closed path or Loop: Starting at an arbitrary selected node, we trace a closed path in a circuit through selected basic circuit elements and return to the original node without passing through any intermediate node more than once.

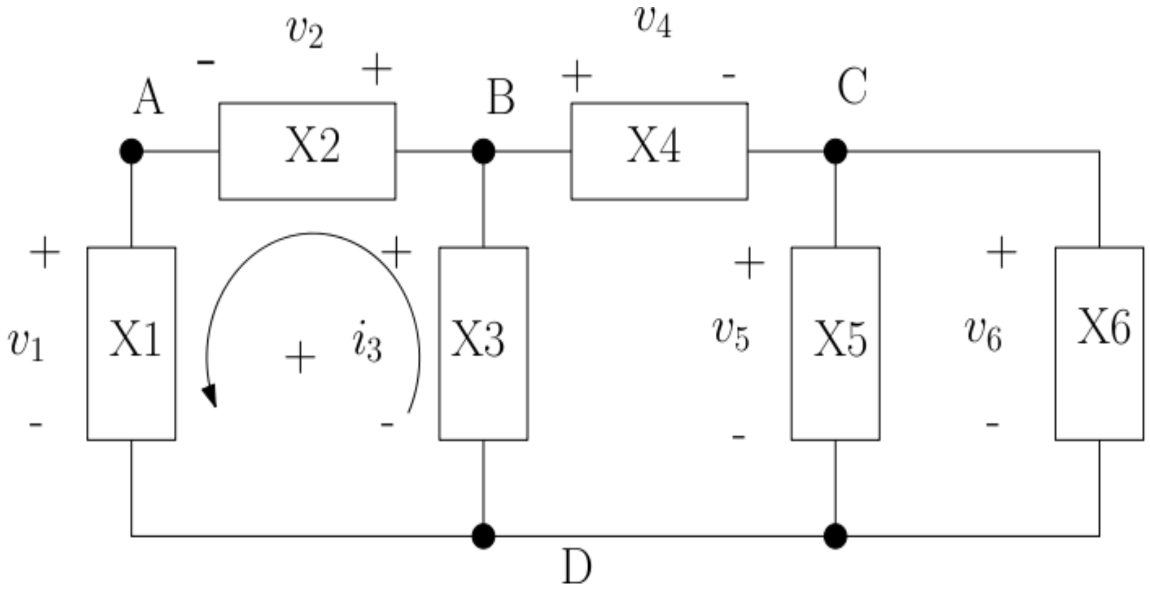
Example 6:

Apply KVL to the circuit shown in the figure



Solution:

Apply KVL to the circuit shown in the figure



Loop (X1 X2 X3)

$$v_1 + v_2 - v_3 = 0$$

$$v_1 + v_2 = v_3$$

Loop (X3 X4 X5)

$$v_3 - v_4 - v_5 = 0$$

$$v_3 = v_4 + v_5$$

Loop (X5 X6)

$$v_5 - v_6 = 0 \quad \rightarrow v_5 = v_6$$

Loop (X1 X2 X4 X5)

$$v_1 + v_2 - v_4 - v_5 = 0$$

$$v_1 + v_2 = v_4 + v_5$$

Loop (X1 X2 X4 X6)

$$v_1 + v_2 - v_4 - v_6 = 0$$

$$v_1 + v_2 = v_4 + v_6$$

Loop (X3 X4 X6)

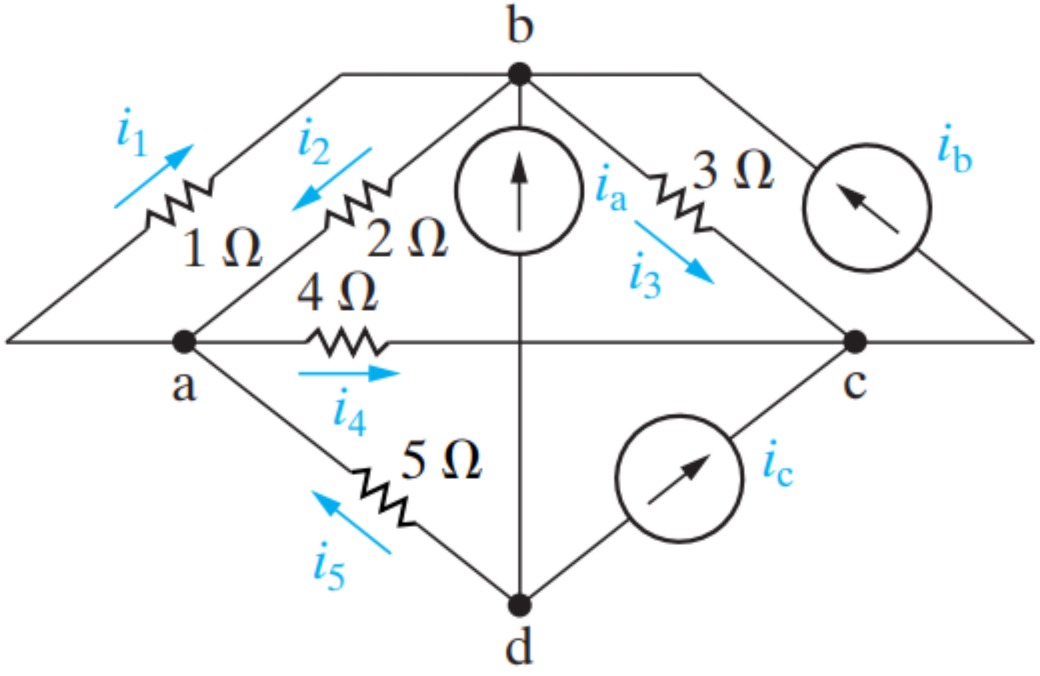
$$v_3 - v_4 - v_6 = 0$$

$$v_3 = v_4 + v_6$$

2-5 Kirchhoff’s Laws

Example 7:

Apply KCL to the circuit shown in the figure



Solution

In writing the equations, we use a positive sign for a current leaving a node. The four equations are

node a $\quad i_1 + i_4 - i_2 - i_5 = 0,$

node b $\quad i_2 + i_3 - i_1 - i_b - i_a = 0,$

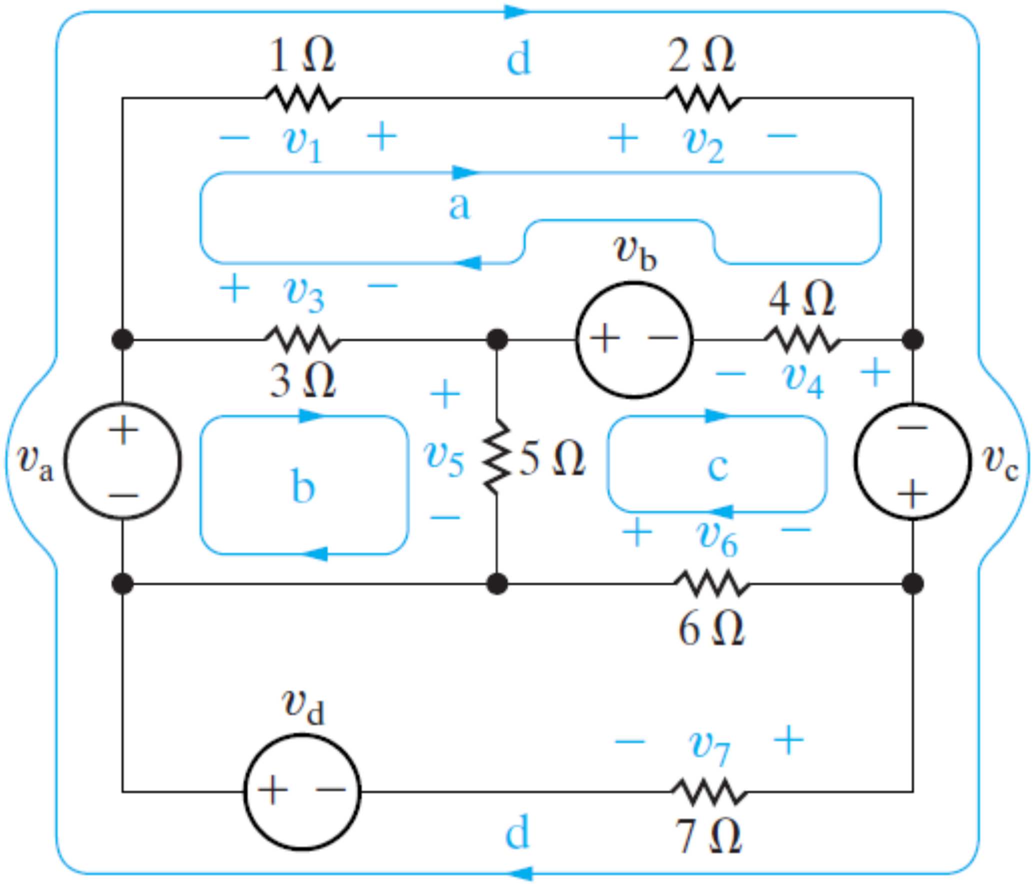
node c $\quad i_b - i_3 - i_4 - i_c = 0,$

node d $\quad i_5 + i_a + i_c = 0.$

2-5 Kirchhoff’s Laws

Example 8:

Apply KVL to the circuit shown in the figure



Solution

In writing the equations, we use a positive sign for a voltage drop. The four equations are

path a $\quad -v_1 + v_2 + v_4 - v_b - v_3 = 0,$

path b $\quad -v_a + v_3 + v_5 = 0,$

path c $\quad v_b - v_4 - v_c - v_6 - v_5 = 0,$

path d $\quad -v_a - v_1 + v_2 - v_c + v_7 - v_d = 0.$