Engineering Circuits Analysis (ICE2002)

Chapter 2. Circuit Elements – Part 1/2

Contents

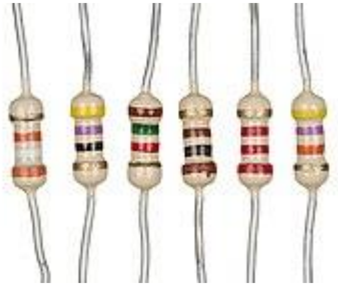
- Voltage and Current Sources
- Electrical Resistance (Ohm's Law)
- Construction of a Circuit Model
- Kirchhoff's Law
- Analysis of a Circuit Containing Dependent Sources

Circuit Elements

Voltage sources

Voltage & current sources

Resistors



Capacitors

Inductors

Circuit Elements

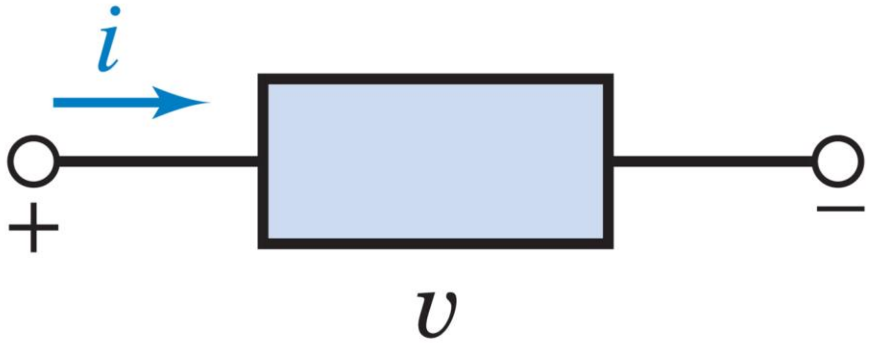
- **5 ideal basic circuit elements**
  - Voltage source
  - Current source
  - Resistor
  - Inductor
  - Capacitor

Active elements, capable of generating electric energy

Passive elements , incapable of generating electric energy

In Chapter 2,

- Voltage sources, current sources, and resistors can be described by plotting the current (i) as a function of the voltage (v).



Electrical Sources

- **An electric source** is a device that is capable of converting non-electrical energy to electrical energy and vice versa.

  - Examples:

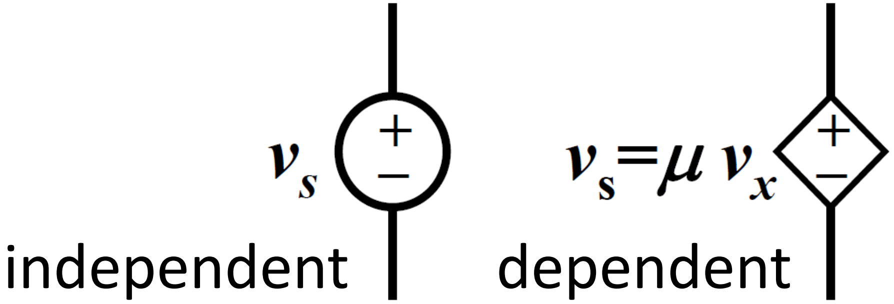
    battery: chemical energy <> electric energy

    dynamo (generator/motor): mechanical energy <> electric energy

  - Ideal voltage source – either independent or dependent
  - Ideal current source – either independent or dependent

Electrical Sources

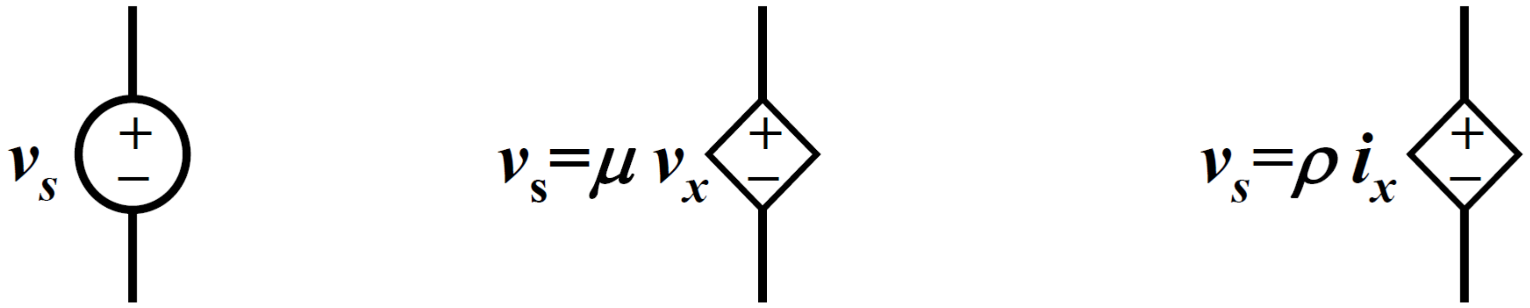
- Independent: the source is independent of any other voltage or current in the circuit.
- Dependent: the source has the output which is dependent upon some other voltage or currents in the circuit. Also, it is called the controlled source.
- Ideal: the source maintains its specified voltage (or current), regardless of the current in (or voltage across) the source.



Circle is used to represent an independent source
Diamond is used to represent a dependent source

Ideal Voltage Source

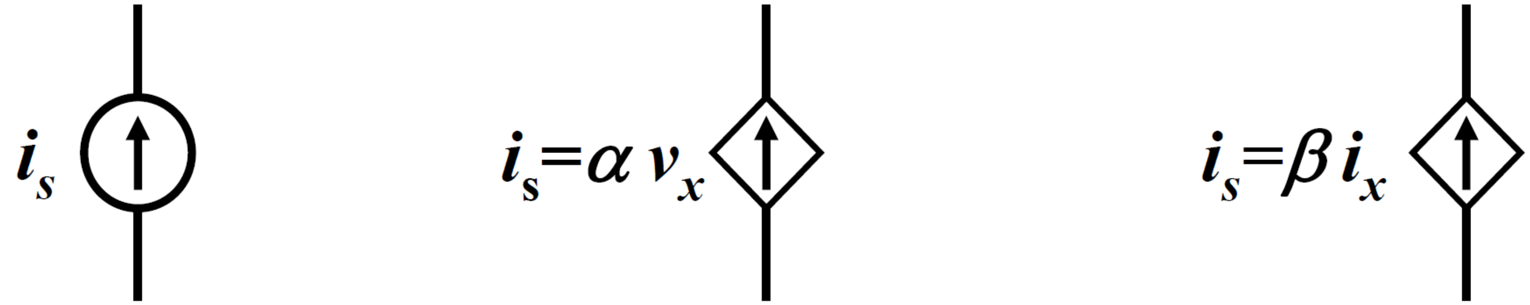
- Circuit element that maintains a prescribed voltage across its terminals, regardless f the current flowing in those terminals.
  - Voltage is known, but current is determined by the circuit to which the source is connected.
- The voltage can be either independent or dependent on a voltage or current elsewhere in the circuit and can be constant or time-varying.



independent   Voltage-controlled   current-controlled

Ideal Current Source

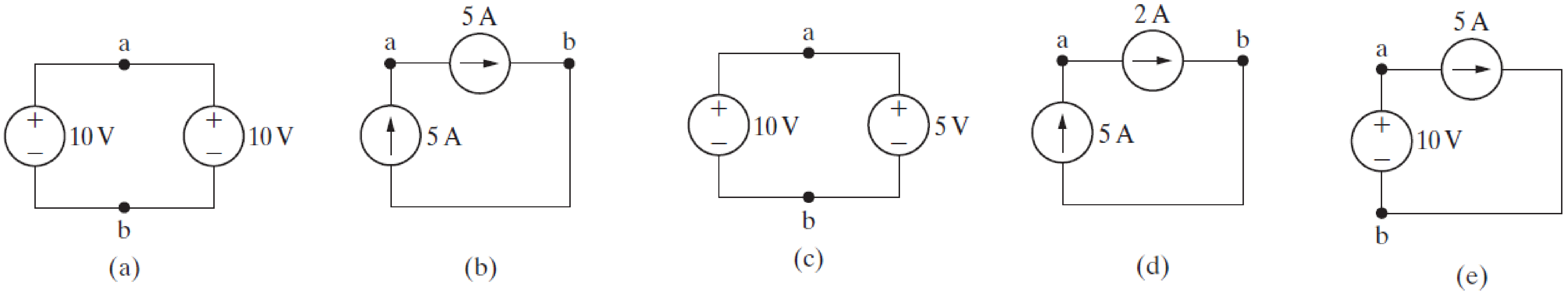
- Circuit element that maintains a prescribed current through its terminals, regardless of the voltage across those terminals.
  - Current is known, but voltage is determined by the circuit to which the source is connected.
- The current can be either independent or dependent on a voltage or current elsewhere in the circuit and can be constant or time-varying.



independent | Voltage-controlled | current-controlled

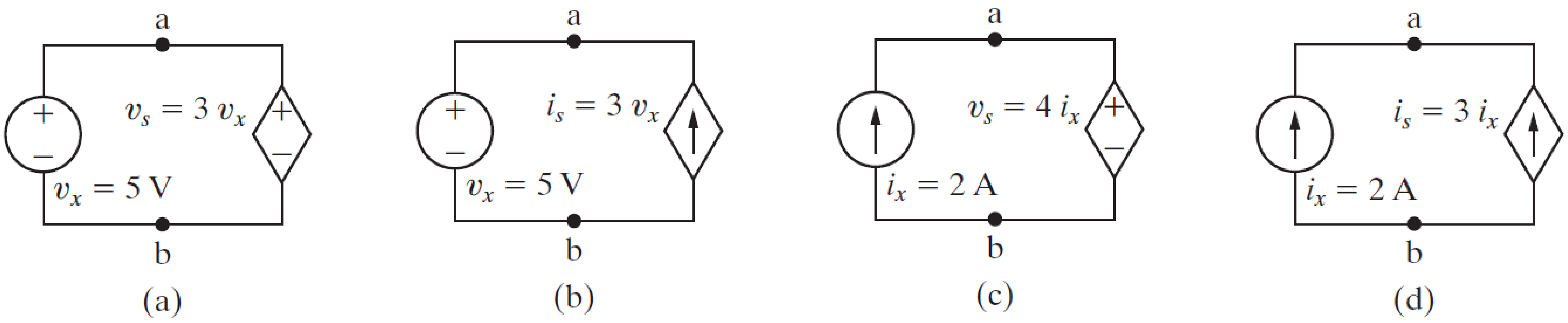
Example 2.1

Q. Use the definitions of the ideal independent voltage and current sources to determine which interconnection are permitted and violated.



Example 2.2

Q. State which interconnections are permitted and violated, using the definitions of the ideal independent and dependent sources.



Electrical Resistance

- Resistance (R) is the capacity of materials to impede the flow of current or the flow of electric charge. The circuit element used to model this behavior is the resistor.
- It is measured in ohm [Ω].

$$R = \frac{\rho L}{A}$$

where
ρ = the resistivity of the material,
L = the length of the conductor,
A = the cross-sectional area of the conductor.

Electrical Conductance

- Conductance (G) is the ability of an element to conduct electric current. It is the reciprocal of resistance R and it is measured in 1/Ω or siemens [S].

$$G = \frac{1}{R}$$

where
R = the resistance in ohms.

$$R = \frac{\rho L}{A}$$

where
ρ = the resistivity of the material,
L = the length of the conductor,
A = the cross-sectional area of the conductor.

Ohm's Law

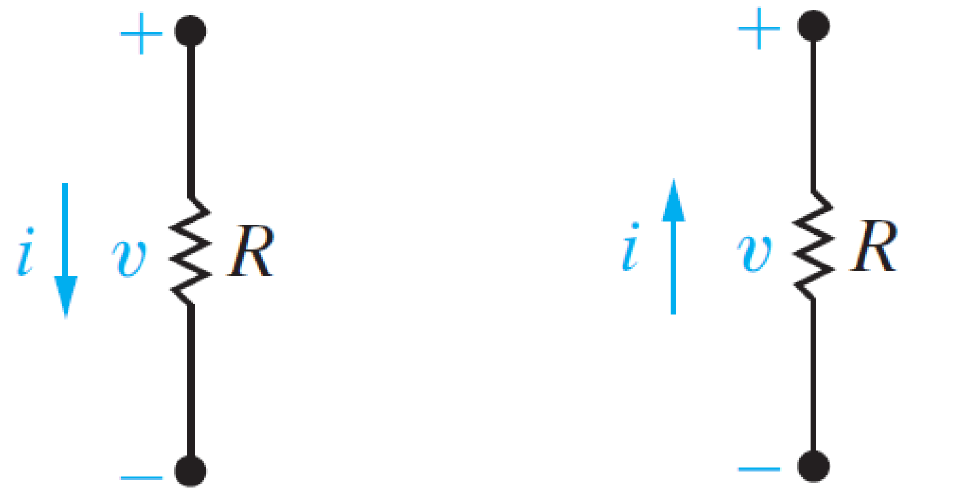
- Ohm's law establishes the proportionality of voltage and current in a resistor. It states that the voltage across a resistor is directly proportional to the current I flowing through the resistor.
- Two extreme possible values of R:
  zero (R = 0) – short circuit and infinite – open circuit

$$v = Ri$$

where
v = the voltage in volts,
i = the current in amperes,
R = the resistance in ohms.

Ohm’s Law

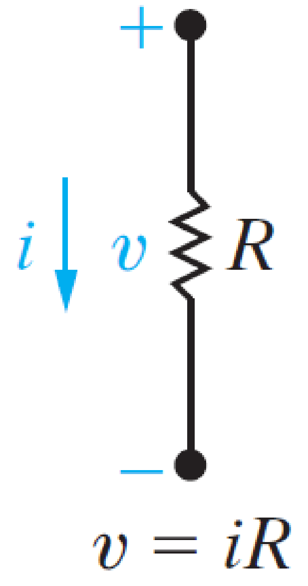
- If the current flow in the resistor is in the direction of the voltage drop across it >> (a)
- If the current flow in the resistor is in the direction of the voltage rise across it >> (b)



(a) $v = iR$ (b) $v = -iR$

Ohm's Law – Power

- Power in a resistor, in terms of current (*i*) or voltage (*v*):



In Chapter 1,

$$p = \frac{dw}{dt} = \frac{dw}{dq} \cdot \frac{dq}{dt} = v \cdot i$$

where
p = the power in watts,
w = the energy in joules,
t = the time in seconds.

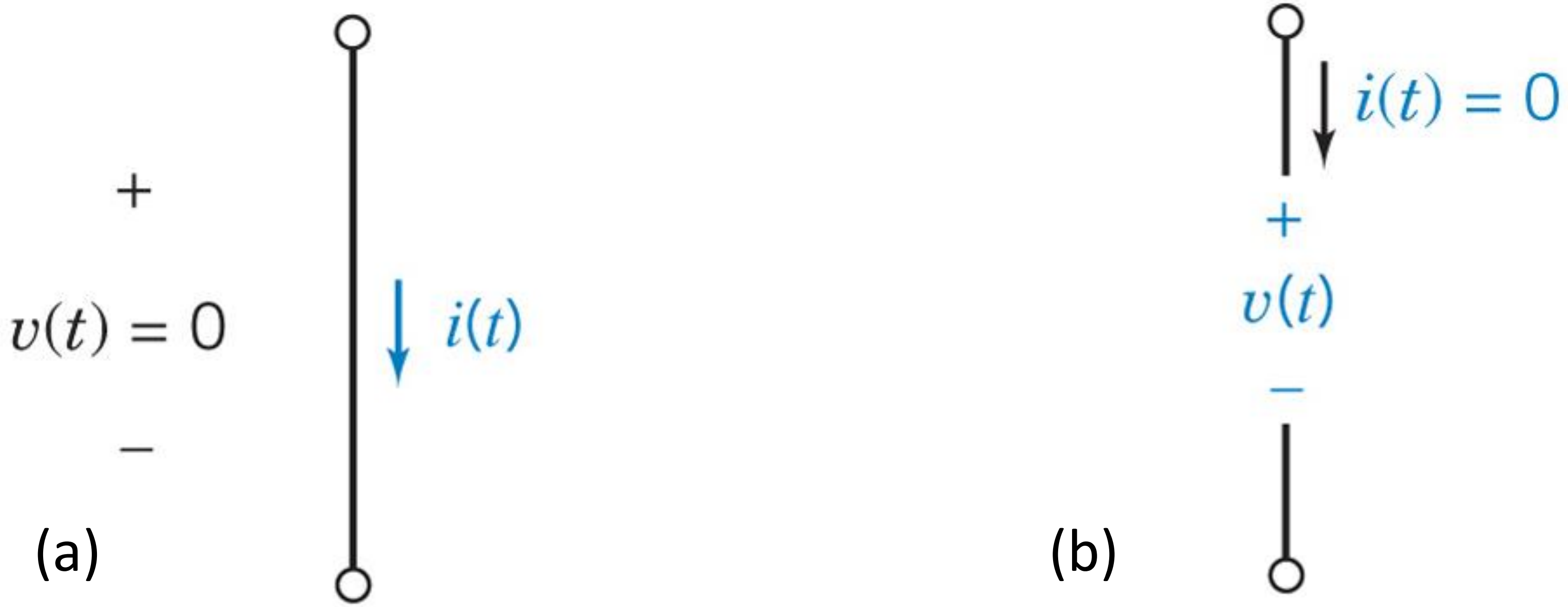
And using the equation $v = iR$

$$P = vi = \frac{v^2}{R} = i^2 R$$

where
v = the voltage in volts,
i = the current in amperes,
R = the resistance in ohms.

Ohm's Law – Short Circuit and Open Circuit

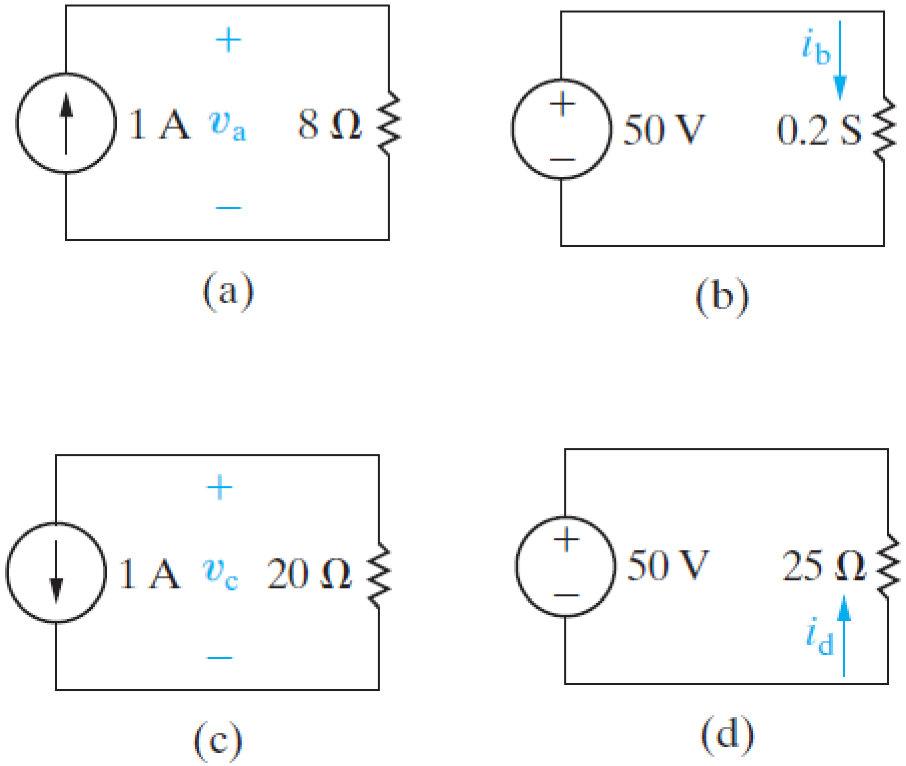
- Two extreme possible values of R:
  (a) Zero (R = 0) – short circuit >> no voltage difference
  (b) Infinite – open circuit >> no current flow



Example 2.3

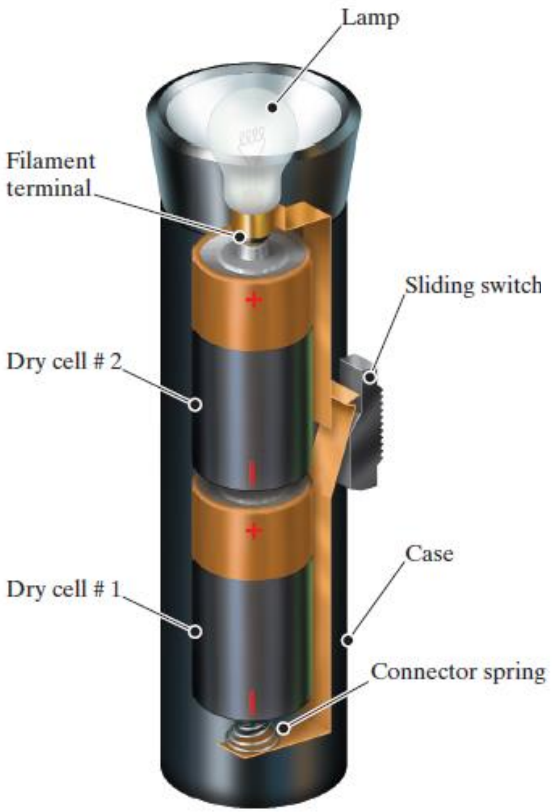
Q. a) calculate the values of v and i

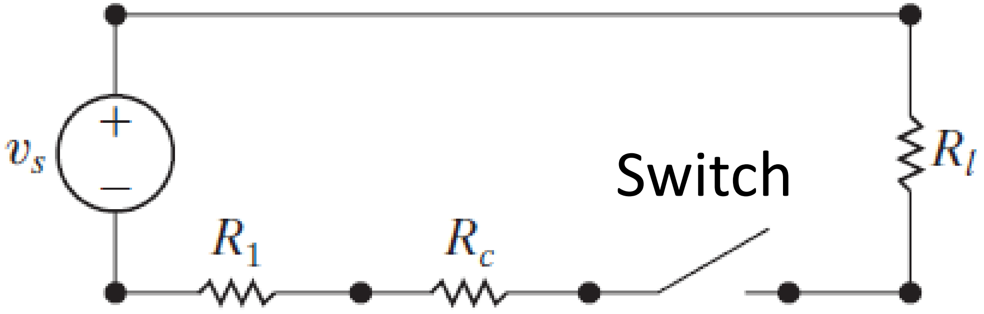
b) Determine the power dissipated in each resistor



Construction of a Circuit Model

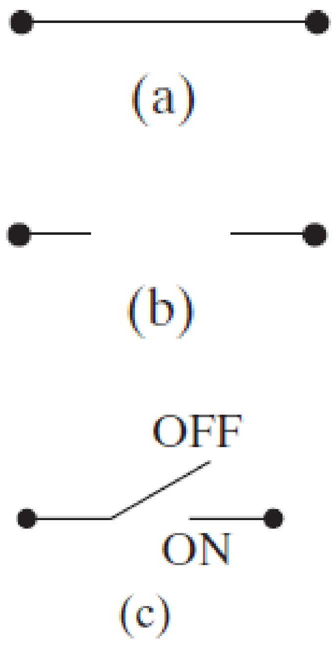
- A circuit model for a flashlight

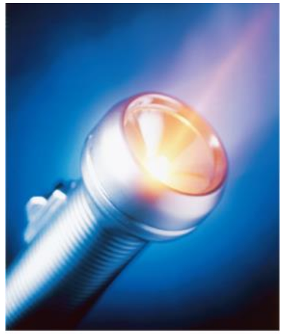




R_l = The resistance of lamp
R_1= The resistance of connector
R_c= The resistance of case

Switch





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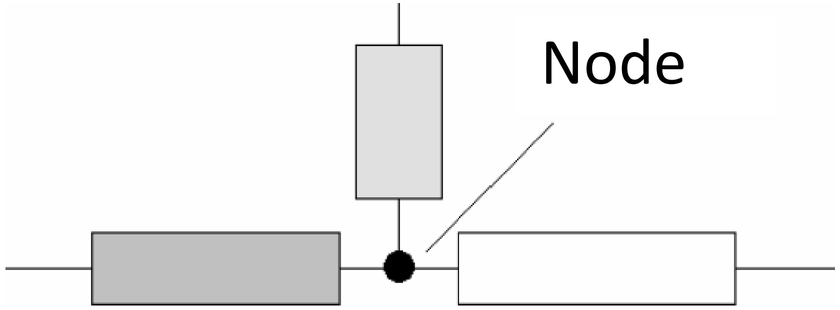
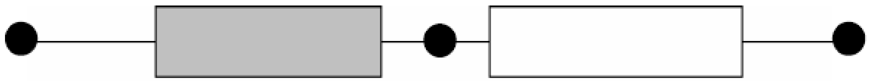
Terminology

- Node: a point where two or more circuit elements are connected

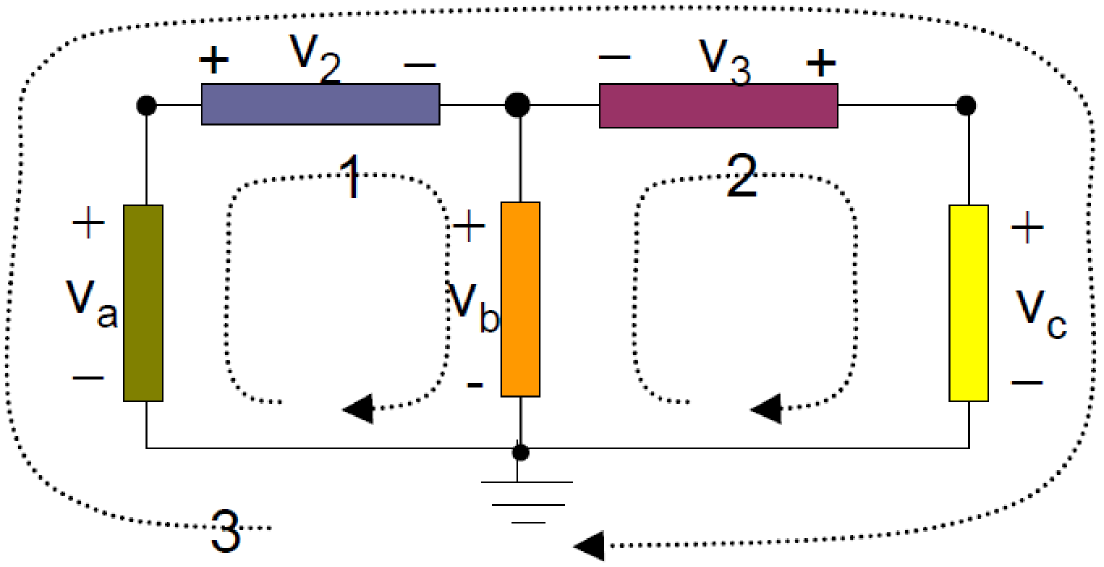
- Branch: a single element such as a voltage source or a resistor; a branch represents any two-terminal element



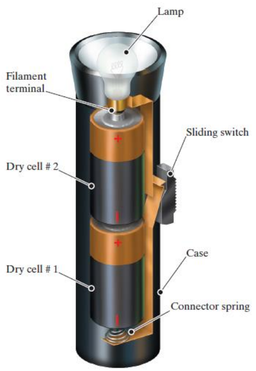


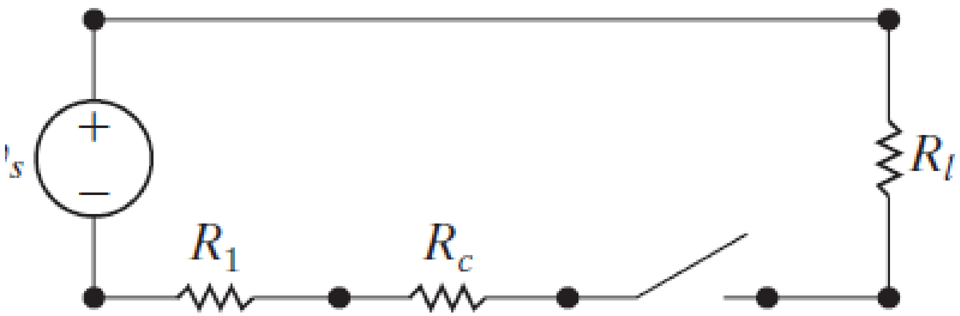
Terminology

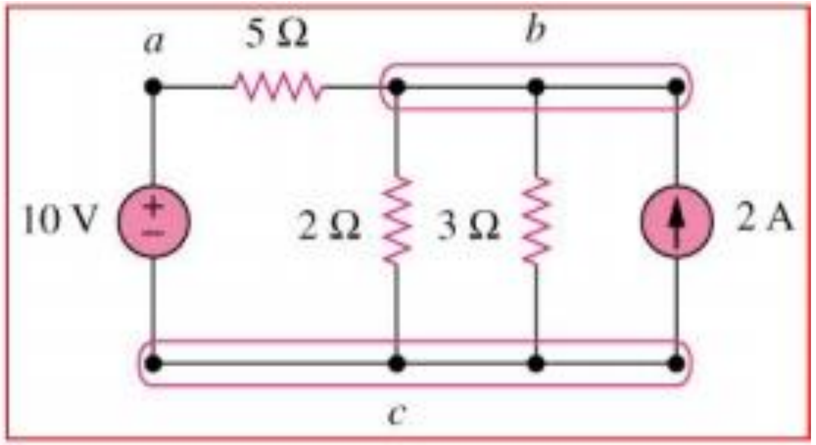
- Closed path (or Loop): it represents a loop traced through connecting elements, starting and ending at the same node and encountering intermediate nodes only once each.

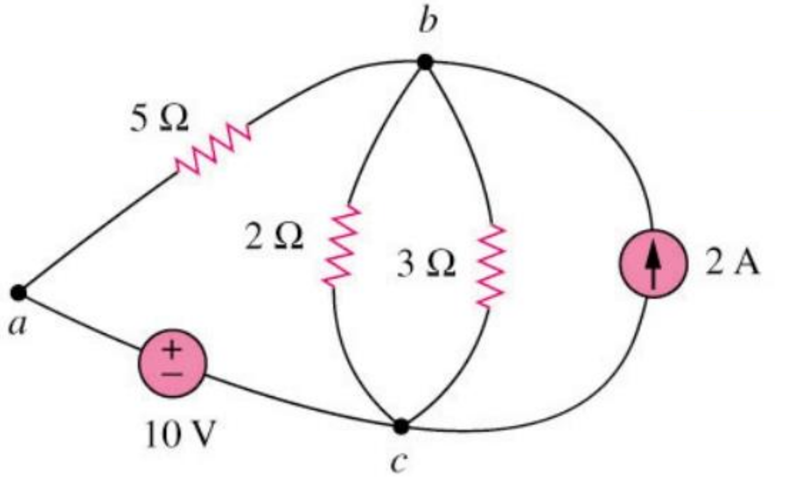


Examples of nodes, branches, and loops



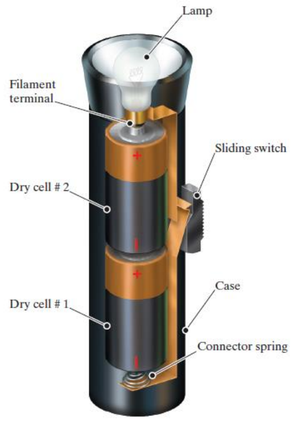


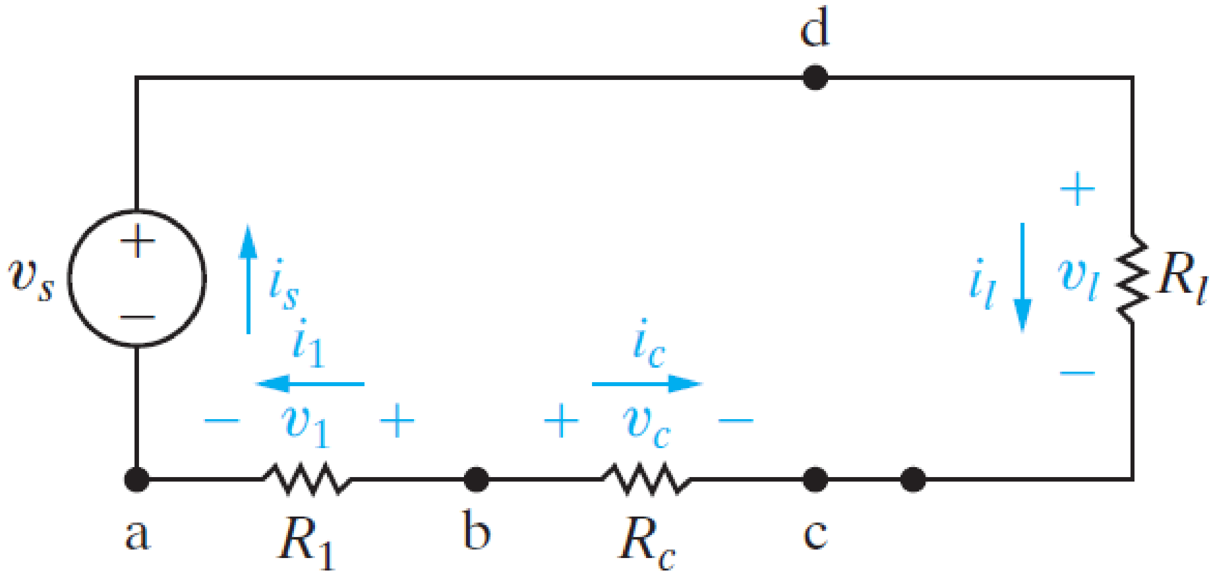




Kirchhoff's Law

- Circuits are described by nodes and closed paths.
- While Ohm's law is an important tool for solving a circuit, it may not be enough to provide a complete solution. >> need Kirchhoff's Law





Using Ohm's law,

Kirchhoff's Law

- Kirchhoff's Current Law (KCL)
  The algebraic sum of all the currents at any node in a circuit equals zero

- Kirchhoff's Voltage Law (KVL)
  The algebraic sum of al the voltages around any closed path in a circuit equals zero

For KCL

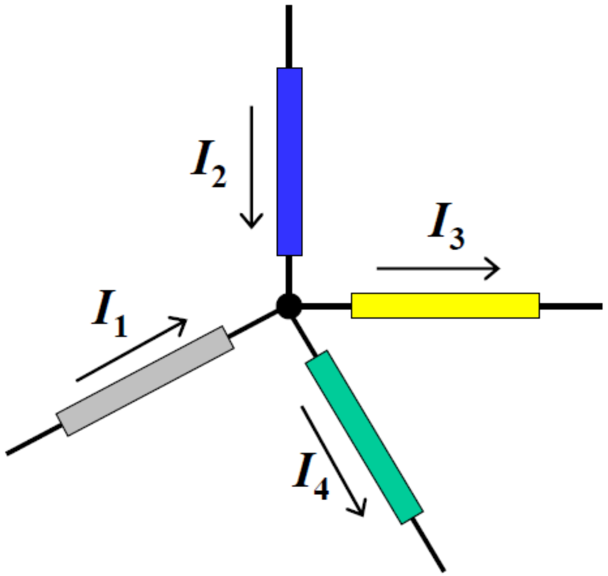
$$\sum_{i=1}^{N} I_i = 0$$

For KVL

$$\sum_{i=1}^{N} V_i = 0$$

Kirchhoff's Law - KCL

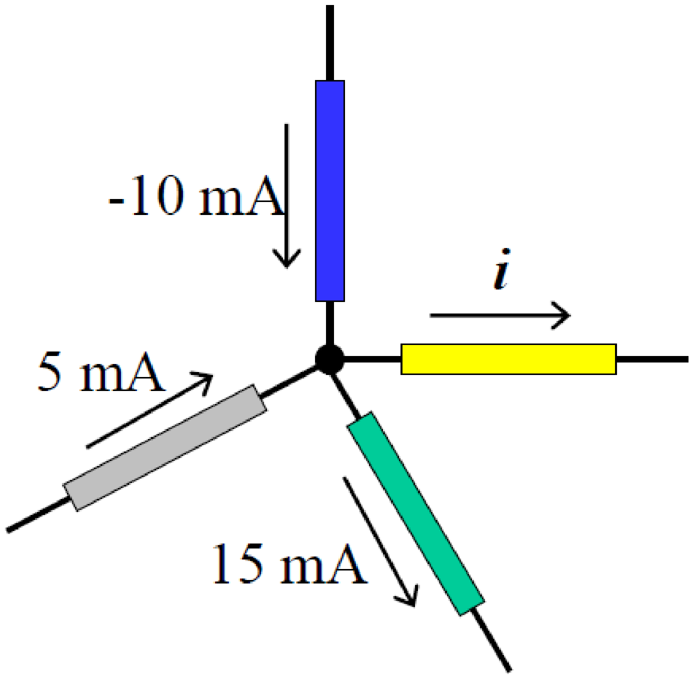
- Kirchhoff's Current Law (KCL)
  - The algebraic sum of all the currents at any node in a circuit equals zero
  - Use reference directions to determine whether currents are "entering" or "leaving" the node



$$\sum_{i=1}^{N} I_i = 0$$

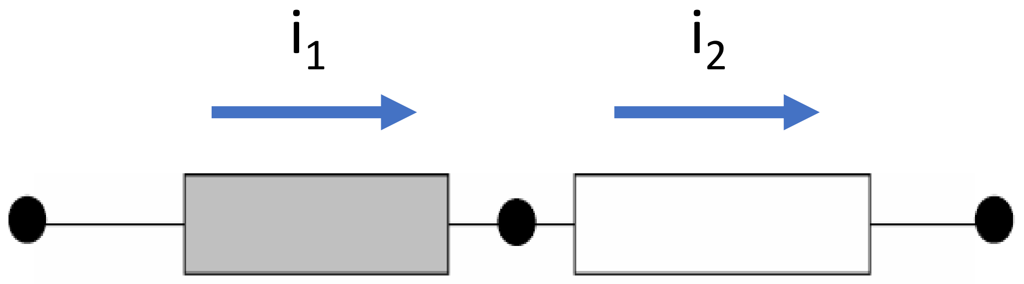
Kirchhoff's Law - KCL

- Kirchhoff's Current Law (KCL)
  - algebraic sum of currents entering node = algebraic sum of currents leaving node



Kirchhoff's Law - KCL

- Kirchhoff's Current Law (KCL)
  - All of the elements in a single branch carry the same current. These components are connected in series.
    current entering node = current leaving node

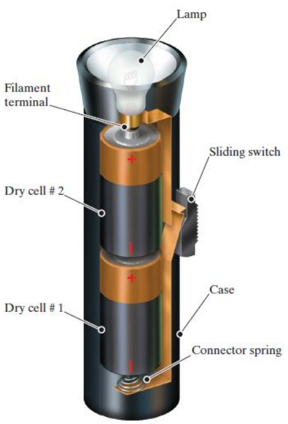


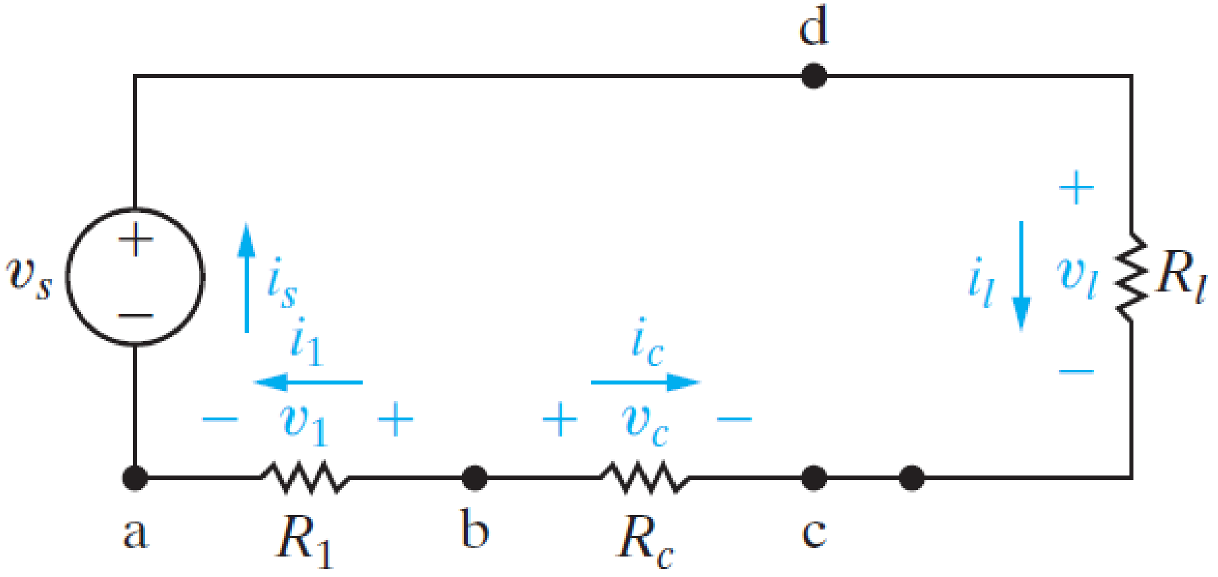
$i_1 = i_2$

Single branch

Kirchhoff's Law - KCL

- Kirchhoff's Current Law (KCL)
  - The algebraic sum of all the currents at any node in a circuit equals zero

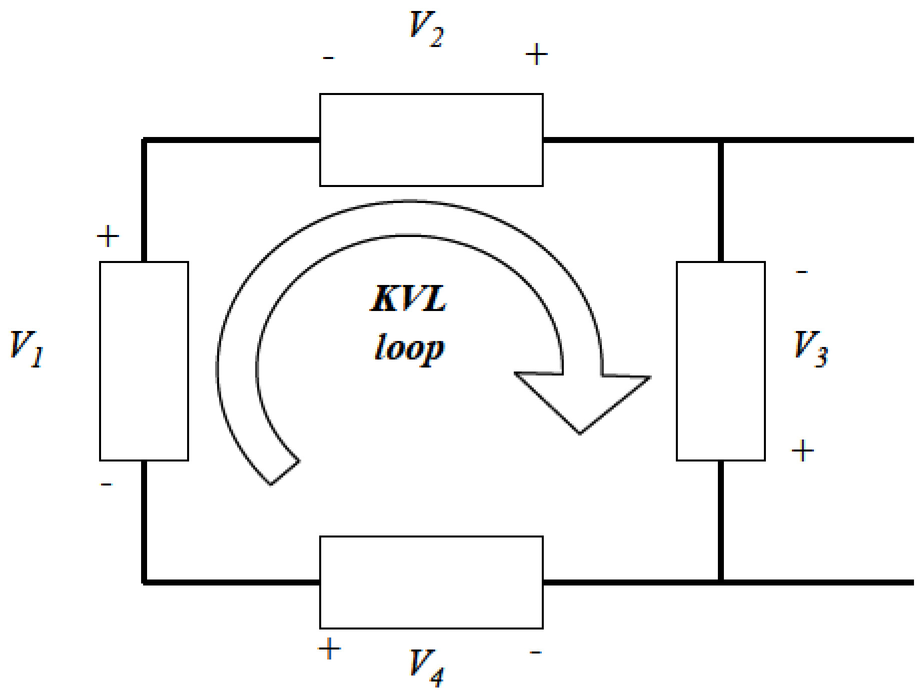




Using KCL,

Kirchhoff's Law - KVL

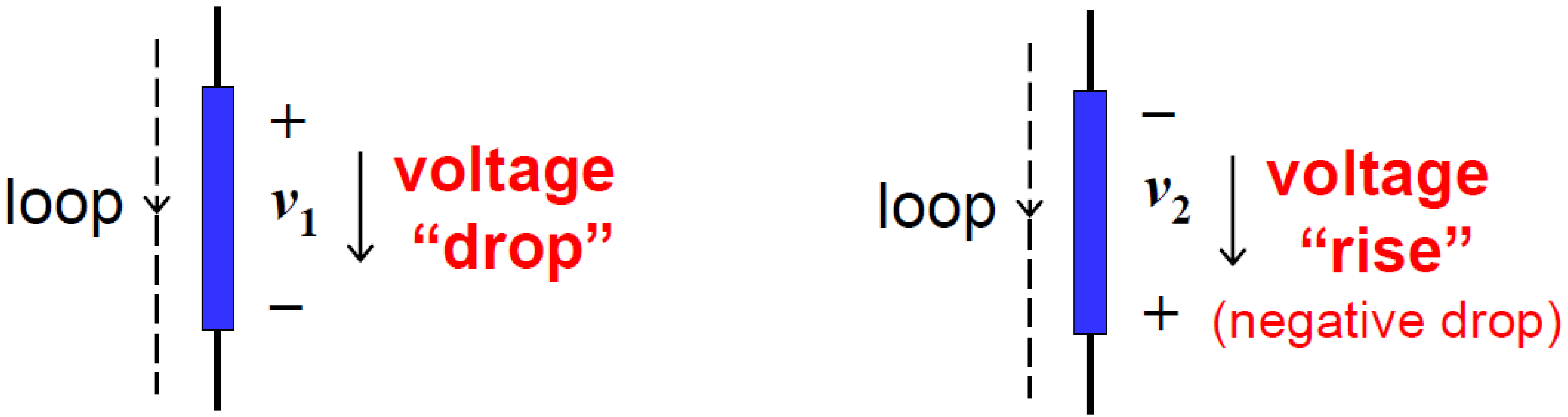
- Kirchhoff's Voltage Law (KVL)
  The algebraic sum of al the voltages around any closed path in a circuit equals zero



$$\sum_{i=1}^{N} V_i = 0$$

Kirchhoff's Law - KVL

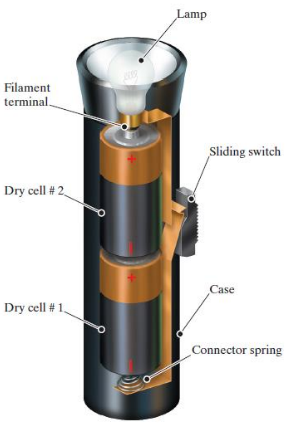
- Kirchhoff's Voltage Law (KVL)
  - Use reference polarities to determine whether a voltage is dropped

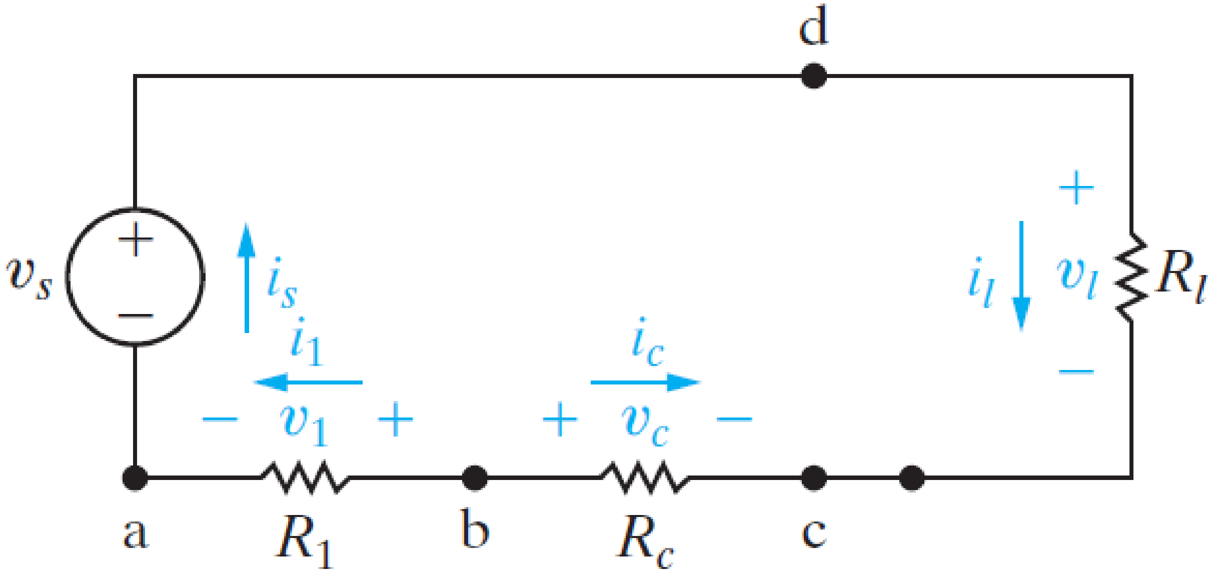


Kirchhoff's Law - KVL

- Kirchhoff's Voltage Law (KVL)

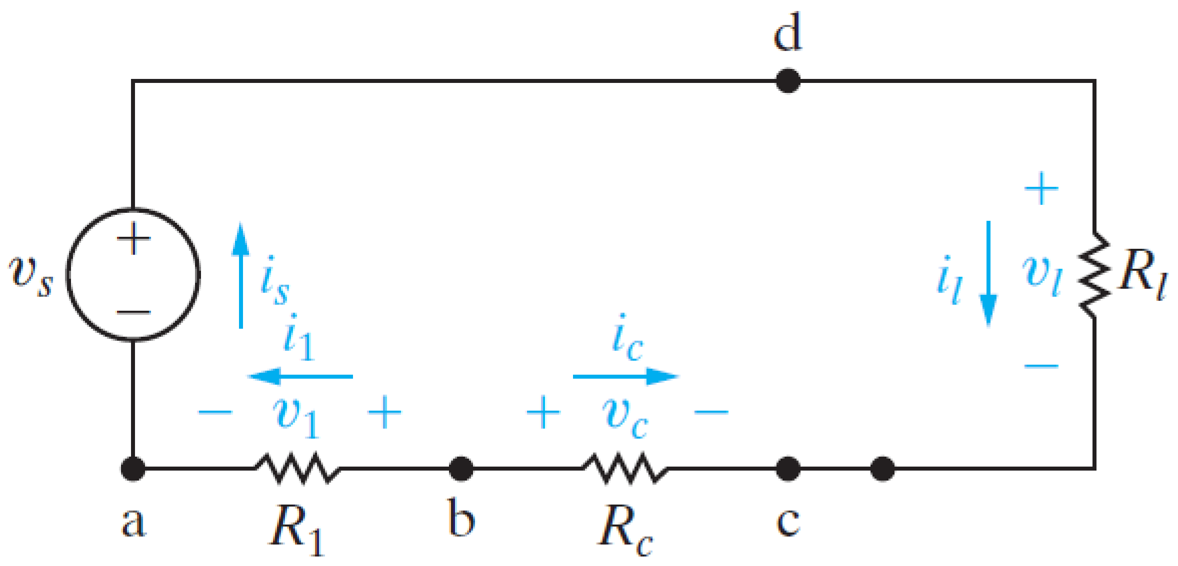
  The algebraic sum of al the voltages around any closed path in a circuit equals zero





Using KVL,

Ohm's law and Kirchhoff's Law



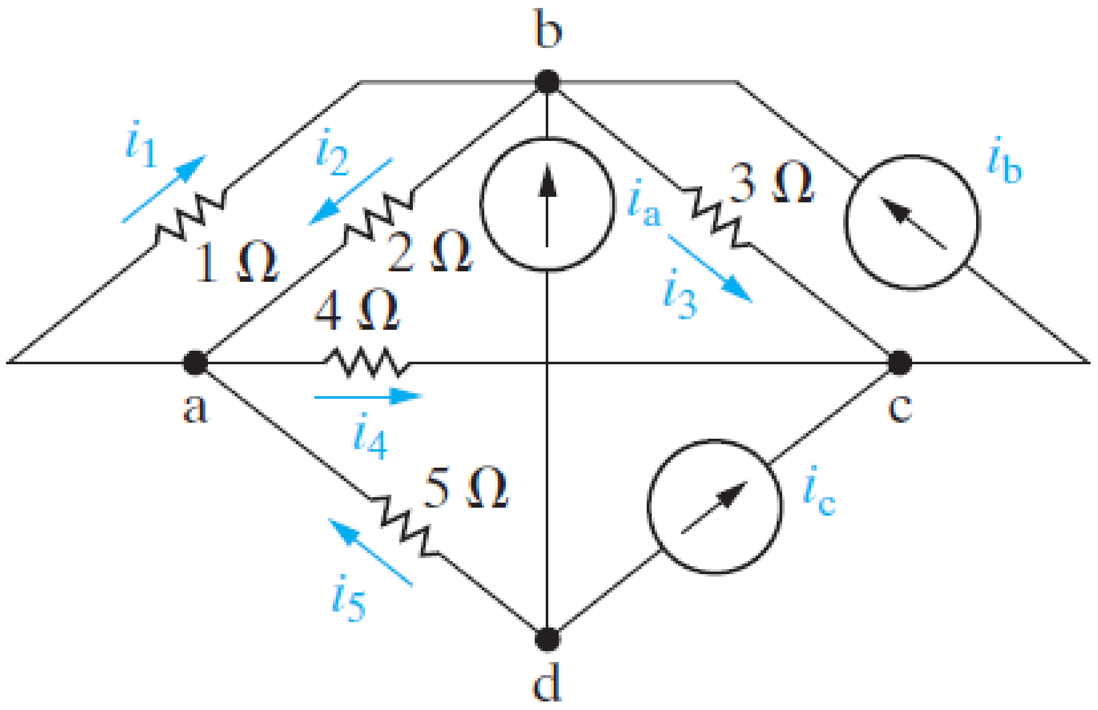
Using Ohm's law,

Using KCL,

Using KVL,

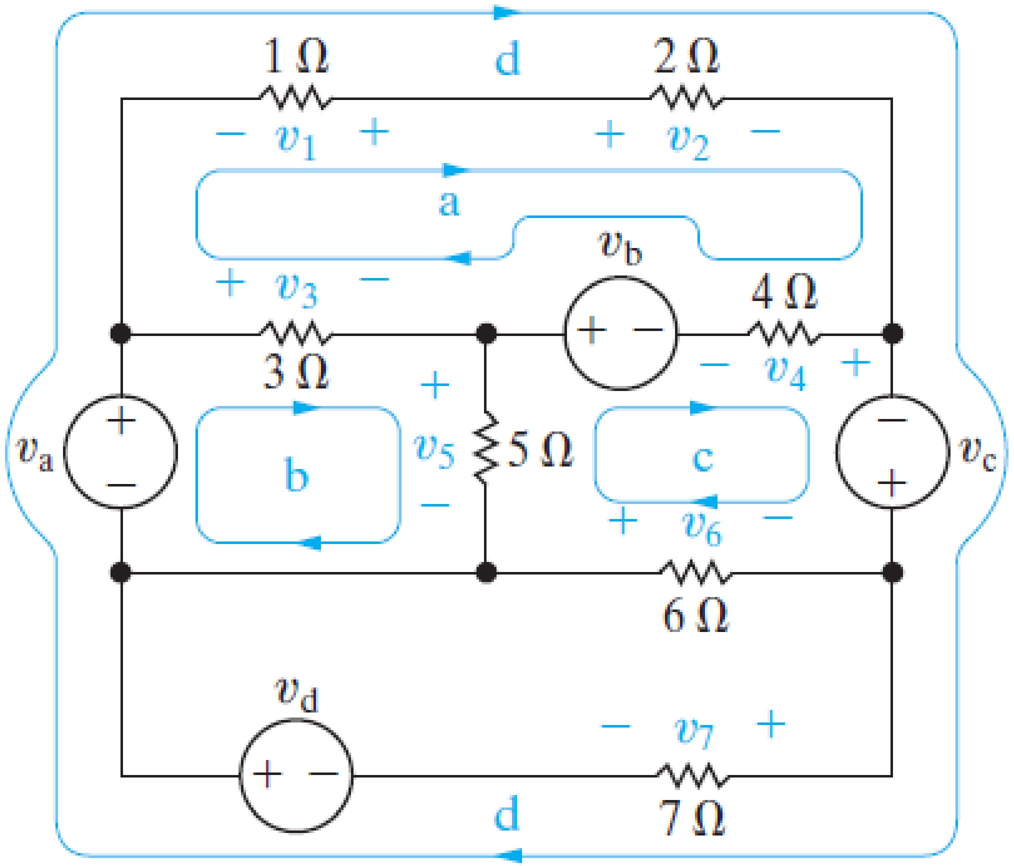
Example 2.6 – KCL

Q. Sum of currents at each node in the circuit



Example 2.7 – KVL

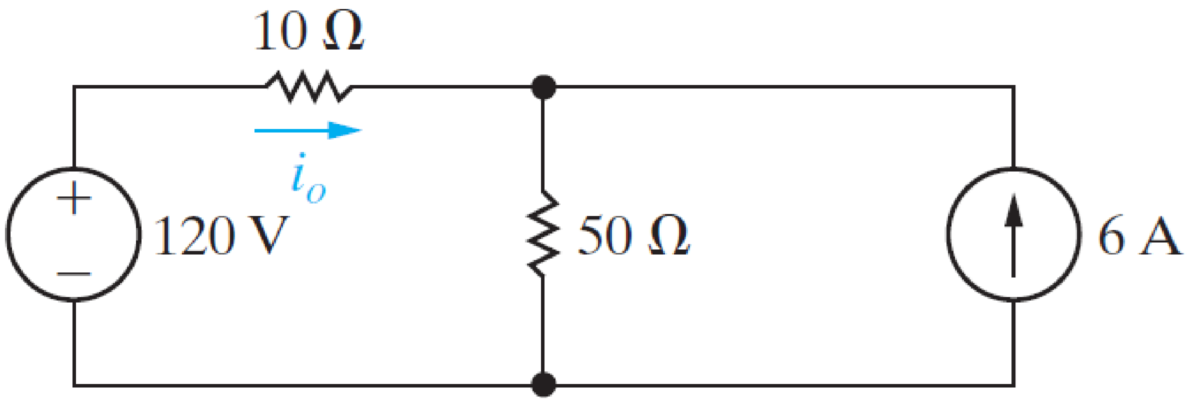
Q. Sum of voltages around each designated path in the circuit



Example 2.8 – Ohm's Law/KCL/KVL

Q. a) Use Kirchhoff's law and Ohm's law to find i_0

b) Verify total power generated equals the total power dissipated



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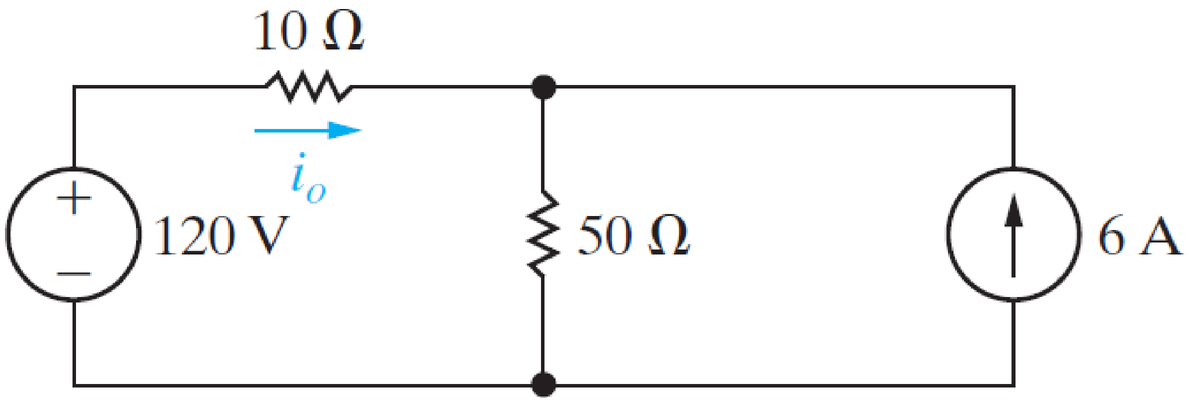
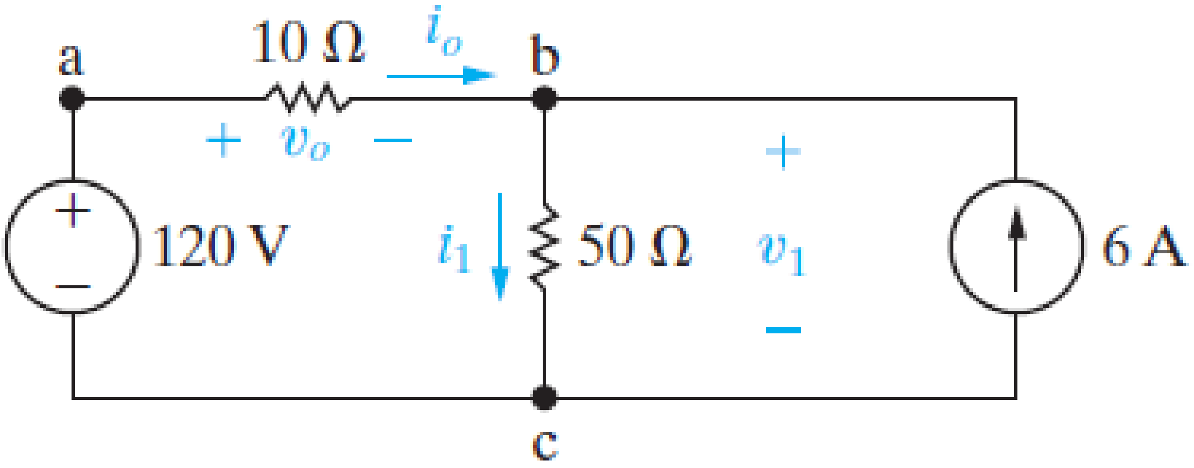
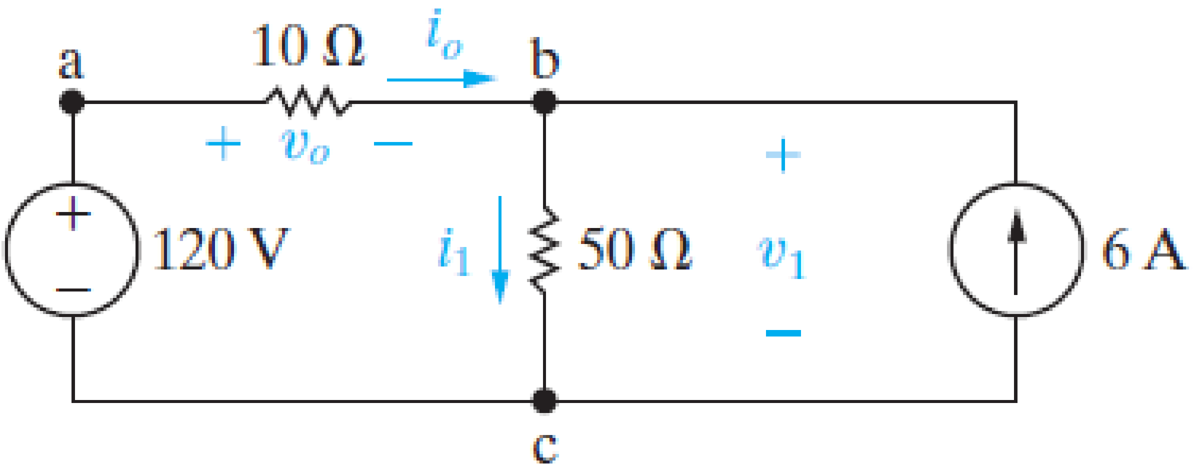




Example 2.8 – Ohm's Law/KCL/KVL

Q. a) Use Kirchhoff's law and Ohm's law to find i_0

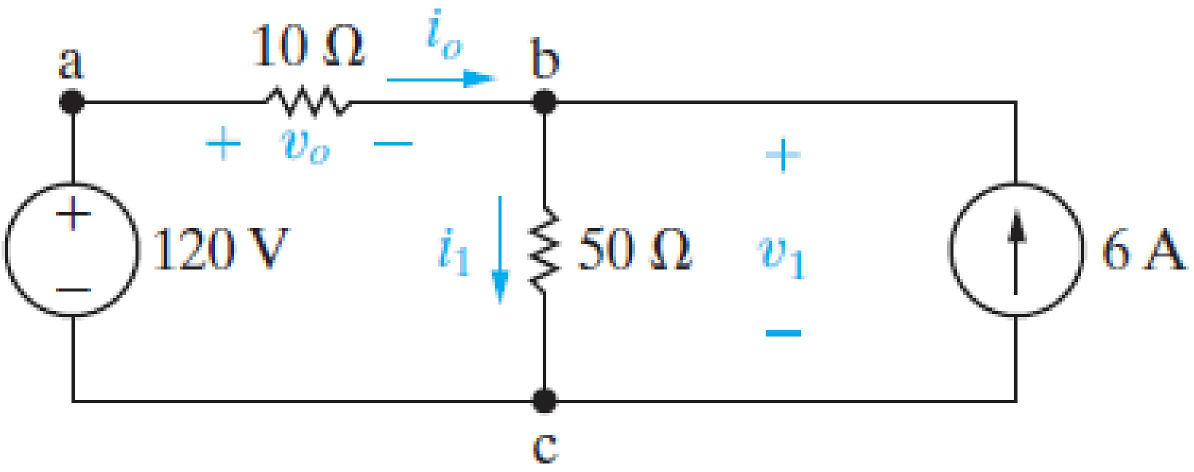
b) Verify total power generated equals the total power dissipated



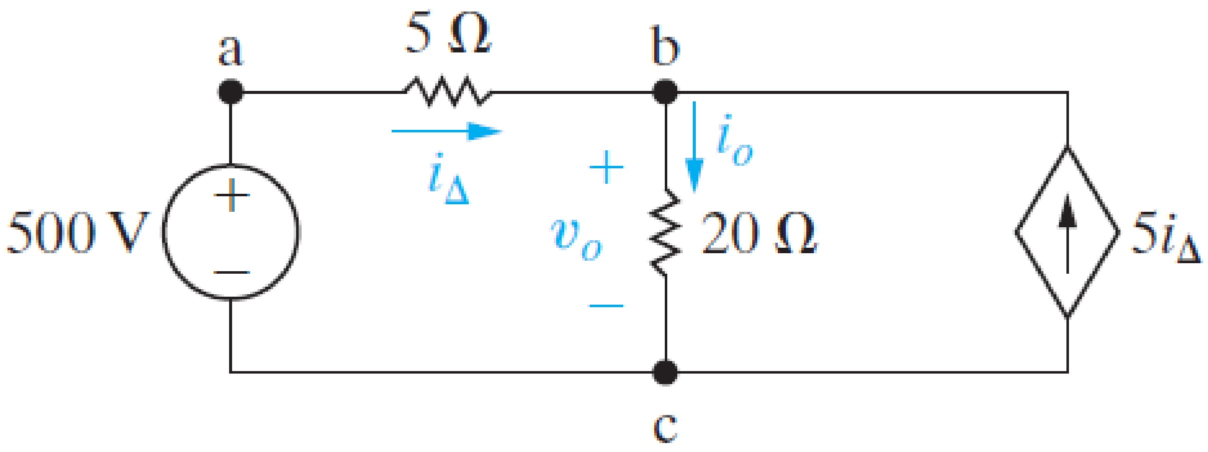
Example 2.8 – Power

Q. a) Use Kirchhoff's law and Ohm's law to find i_0

b) Verify total power generated equals the total power dissipated



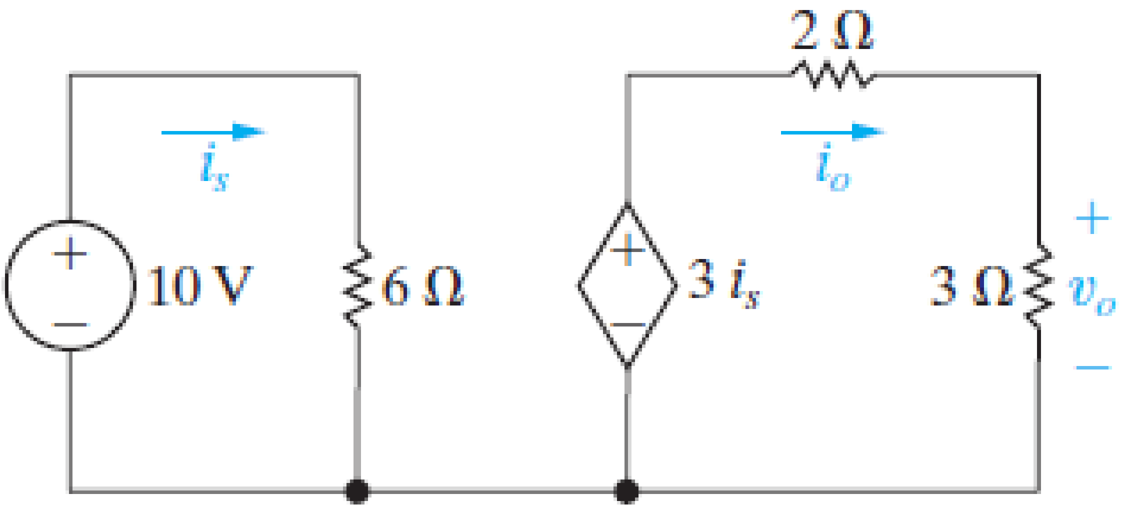
Circuit Containing Dependent Sources



Example 2.11

Q. a) Use Kirchhoff's law and Ohm's law to find v_0

b) Verify total power generated equals the total power dissipated



Summary

- **Circuit elements**
  Active elements: ideal voltage/current source
  Passive elements: resistor/inductor/capacitor

- **Ohm's law**
  The proportionality of voltage and current in a resistor

- **Kirchhoff's law**
  Kirchhoff's Current Law (KCL): the algebraic sum of all the currents at any node in a circuit equals zero
  Kirchhoff's Voltage Law (KVL): the algebraic sum of all the voltage around any closed path in a circuit equals zero