Chapter 2: Circuit Elements

2.1 Voltage and Current Sources

Electrical source: device capable of converting nonelectric energy to electrical energy (battery); is an active element

Active element: models a physical device capable of generating electrical energy

Passive element: models a physical device that is not capable of generating electrical energy (resistor, capacitor, inductor, etc.)

Ideal voltage source: a circuit element that maintains a prescribed voltage regardless of the current in the device

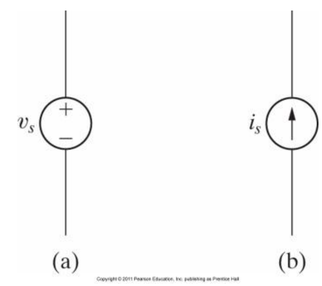
Ideal current source: a circuit element that maintains a prescribed current regardless of the voltage across the device

Note: For an ideal voltage source it is not possible to specify the current as a function of its voltage; for an ideal current source it is not possible to specify the voltage as a function of its current.

2 Types of Sources

Independent: not influenced by other currents or voltages in the circuit

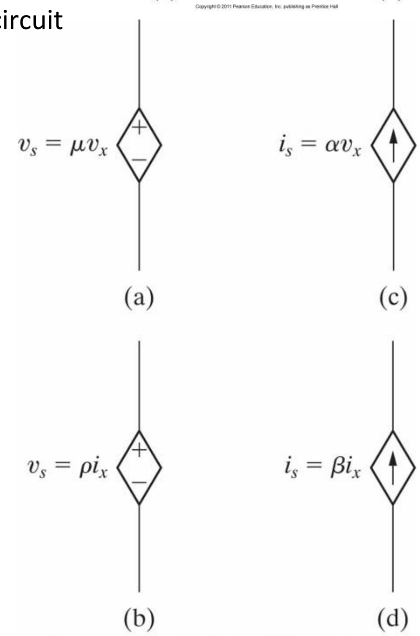
(a) an ideal voltage source
(b) an ideal current source



Dependent: determined by some other current or voltage in the circuit

The circuit symbols for:

(a) an ideal dependent voltage-controlled voltage source
(b) an ideal dependent current-controlled voltage source
(c) an ideal dependent voltage-controlled current source
(d) an ideal dependent current-controlled current source.



Where v_x and i_x are the controlling voltage and current

And μ, α, ρ and β are multiplying constants

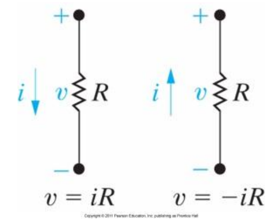
Review Example Problems 2.1 & 2.2 and Assessment Problems 2.1 & 2.2

2.2 Electrical Resistance (Ohm's Law)

Resistance: capacity of materials to impede the flow of electric charge

Resistor: circuit element used to model the behavior of resistance

Ohm's Law $$\boldsymbol{v = iR}$$



Where v = voltage in volts; i is the current in amps; R is the resistance in ohms

Rewriting

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

Given

$$p = vi = (iR)i = \boldsymbol{i^2R}$$

$$p = vi = v\left(\frac{v}{R}\right) = \boldsymbol{\frac{v^2}{R}}$$

The reciprocal of resistance is *conductance* measured in Siemens

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

Thus

$$p = v^2G = \frac{i^2}{G}$$

Review Example Problem 2.3 and Assessment Problems 2.3 & 2.4

2.3 Construction of a Circuit Model

General observations about modeling

- Electrical behavior of each component is of primary interest
- Models need to account for both desired and undesired electrical effects (heat from a light)
- Modeling requires approximations (ignore resistance inherent in some elements)

Example 2.4 – Circuit model for a flashlight

Analyzing:

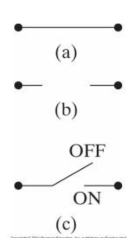
Battery – ideal voltage source (v_s)

Lamp – resistor (R_l)

Switch

Lamp connection – resistor (R_1)

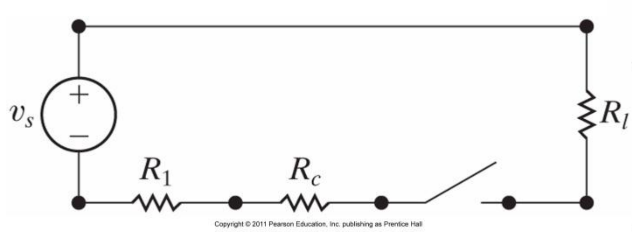
Case connection – resistor (R_l)

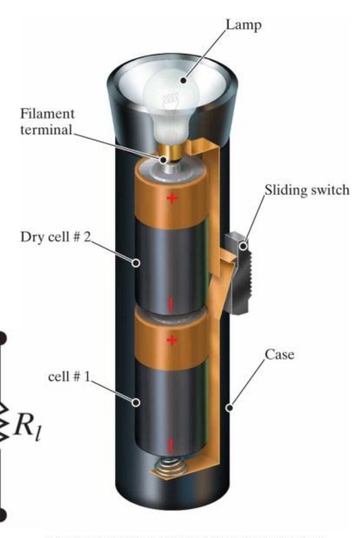


Short circuit (R=0)

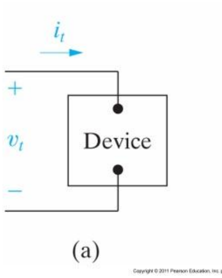
Open Circuit (R=∞)

Switch



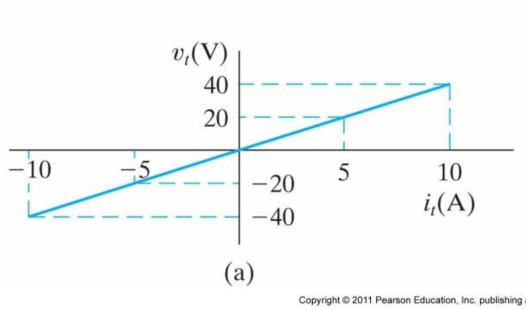


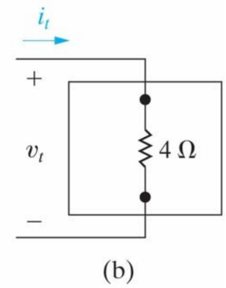
Example 2.5



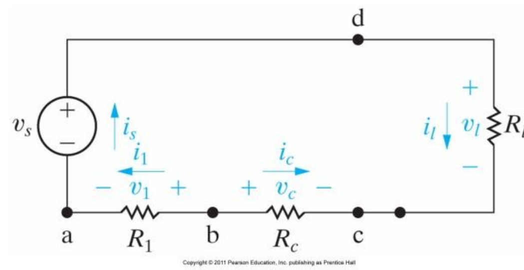
v_t (V)	i_t (A)
−40	−10
−20	−5
0	0
20	5
40	10

(b)





2.4 Kirchhoff's Law



<u>Node:</u> a point where two or more circuit elements meet

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

First a sign for each direction of the current must be assigned:
(positive for current leaving a node; negative when entering)
(negative for current leaving a node; positive when entering)

From the circuit we obtain the following node equations

(a) $i_s - i_1 = 0$ (b) $i_1 + i_c = 0$ (c) $-i_c - i_l = 0$ (d) $i_l - i_s = 0$

Note: for a circuit containing n nodes; n-1 independent current equations can be derived.

<u>Closed loop/path:</u> beginning at any node, 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

Kirchhoff's Voltage Law (KVL): the algebraic sum of all the voltages around a closed path in a circuit equals zero.

First a sign for each voltage must be assigned: (positive for a voltage rise; negative for a voltage drop)
(negative for a voltage rise; positive for a voltage drop)

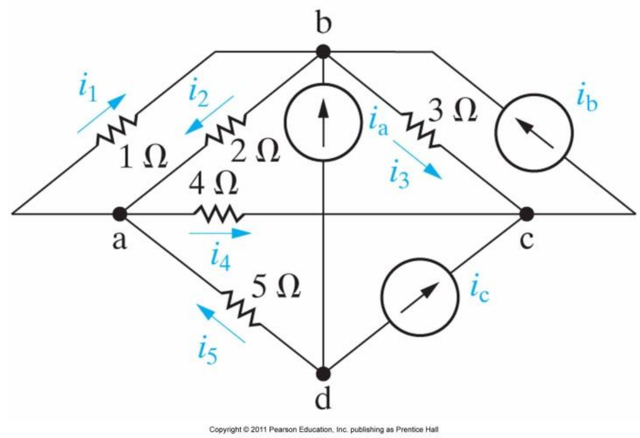
For the circuit starting at node d and tracing a closed path yields:

$$v_l - v_c + v_1 - v_s = 0$$

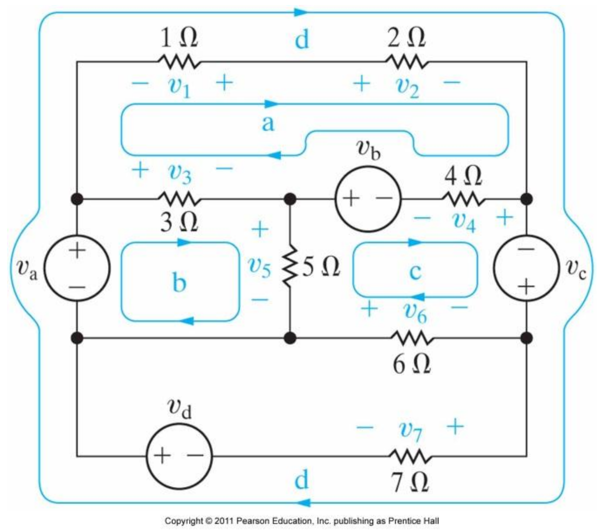
Observations

- If you know either the voltage across or current through a resistor you can determine the other by using Ohm's Law
- When only two elements are connected to a node, if you know the current in one element you know the current in the other. The elements are said to be connected in *series.*

Example 2.6 – Using KCL

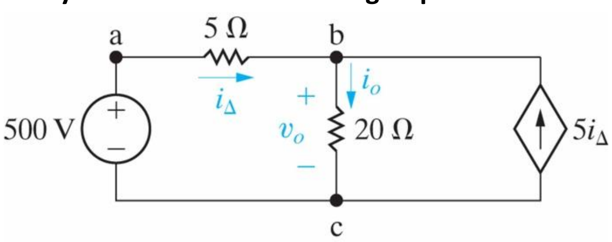


Example 2.7 – Using KVL



Review Examples 2.8 & 2.9 and Assessment Problems 2.5 – 2.8

2.5 Analysis of a Circuit Containing Dependent Sources



Using Kirchhoff's Laws and Ohm's Law to find v_o

- To determine the voltage we must find the two currents.
- KVL for the left path:

$$500 = 5i_\Delta + 20i_o$$

KCL at the top node:

$$5i_\Delta + i_\Delta = i_o = 6i_\Delta$$

Substituting and solving

$$i_\Delta = 4\ A$$
$$i_o = 24\ A$$

Review Example Problems 2.10 & 2.11 and Assessment Problems 2.9 & 2.10