Chapter 2

Circuit Elements

Text: *Electric Circuits,* 9th Edition, by J. Nilsson and S. Riedel
Prentice Hall

Engr 17 Introductory Circuit Analysis
Instructor: Russ Tatro

Section 2.1
Voltage And Current Sources

Overview

An Electrical Source is a device that is capable of converting nonelectric energy to electric energy (and often, vice versa).

For example, a lead acid battery delivering power converts chemical energy into electrical energy.

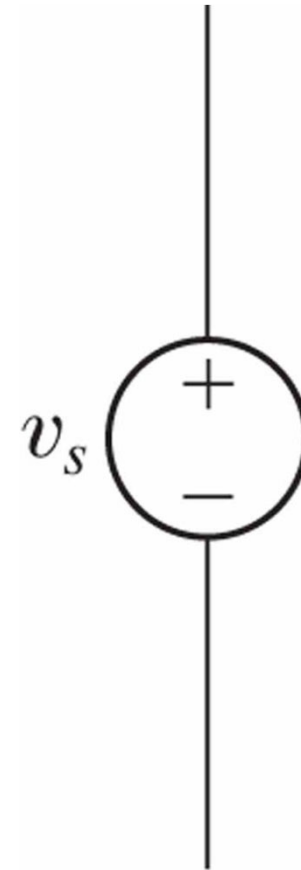A dynamo is a machine that converts mechanical energy into electrical energy.

Ideal Sources

Ideal Voltage Source

Circuit element that maintains a prescribed
voltage across its terminals regardless of the
current flowing in those terminals.

v_s $\left(\begin{array}{c} + \\ - \end{array}\right)$

Voltage is "set".

Current is determined by external circuit to which the voltage source is
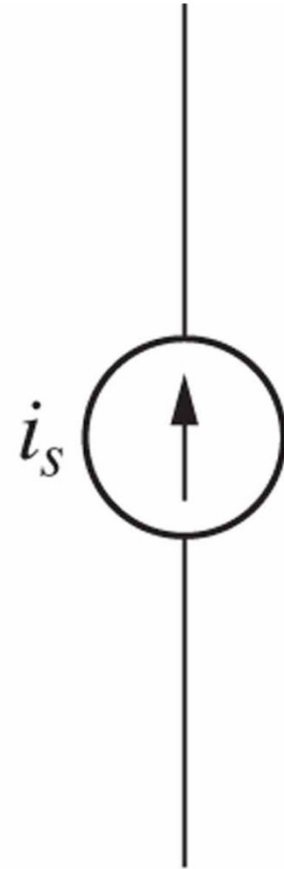connected.

Ideal Sources

Ideal Current Source

Circuit element that maintains a prescribed current through its terminals regardless of the voltage across in those terminals.
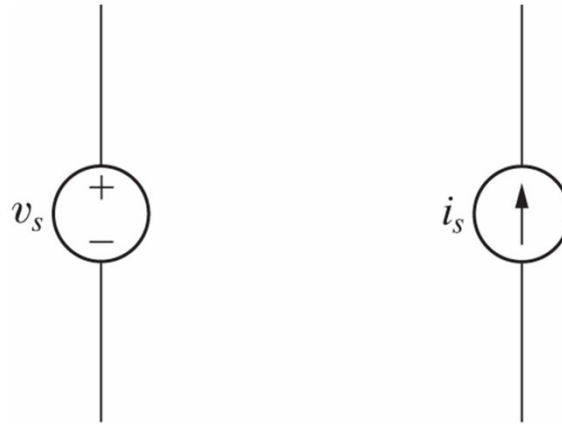
i_s

Current is "set".

Voltage is determined by external circuit to which the current source is connected.
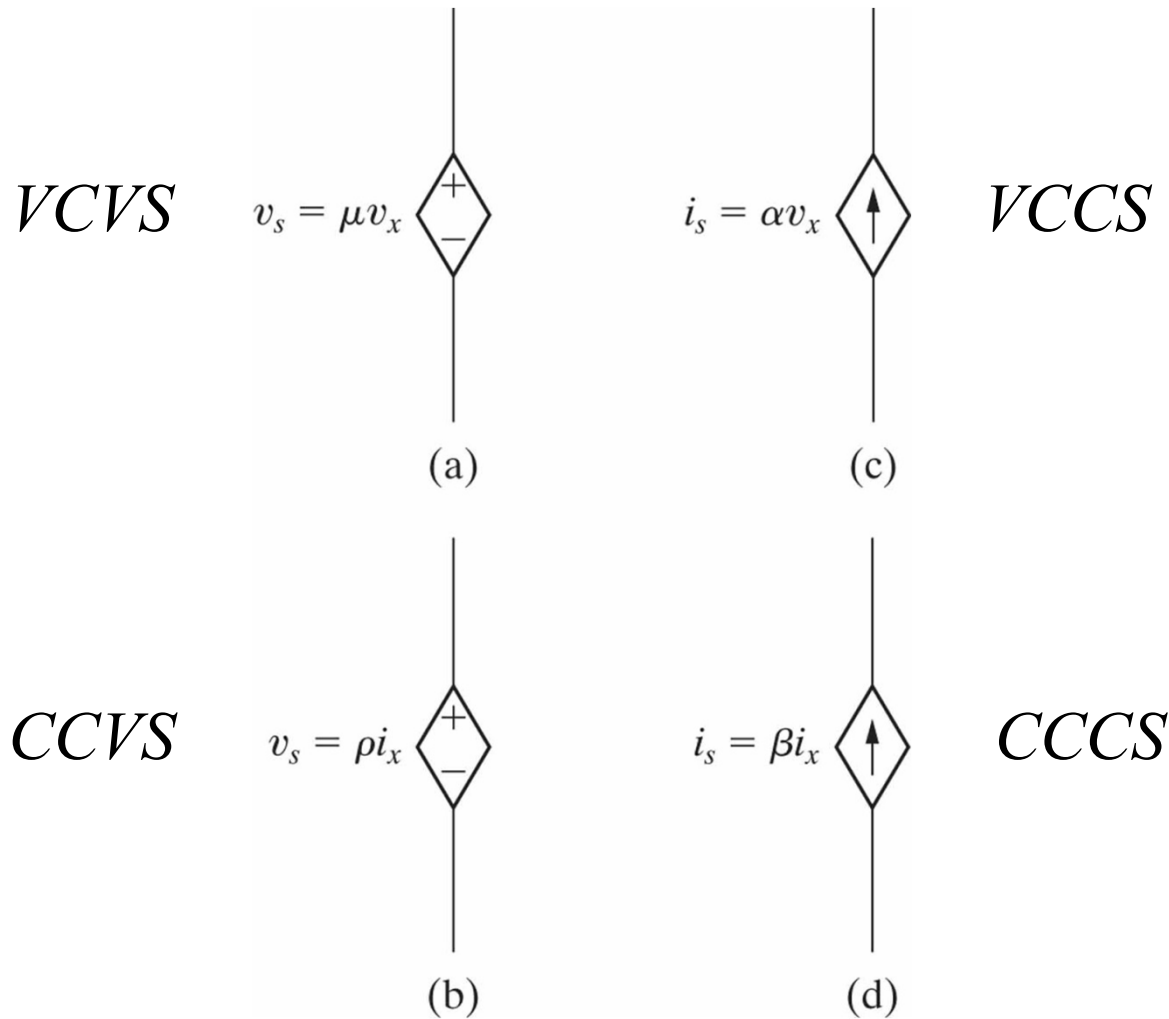
Independent Sources

Independent Source

The prescribed value (current or voltage is not determined by some other circuit variable.

Dependent Source

The prescribed value (current or voltage is determined by some other circuit variable.

VCVS $\qquad v_s = \mu v_x$ (a)

$i_s = \alpha v_x$ VCCS (c)

CCVS $\qquad v_s = \rho i_x$ (b)

$i_s = \beta i_x$ CCCS (d)

Section 2.2
Ohm's Law

Resistance

Resistance is the capacity of materials to impeded the flow of electrical charge.

It impedes the flow by creating heat (usually).

Resistance is one of three main concepts:
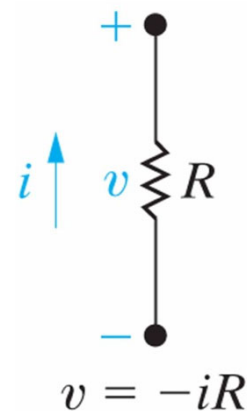
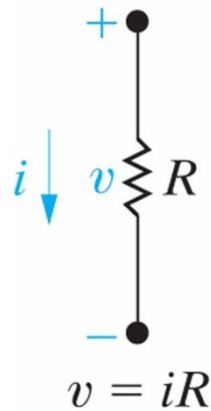$R \rightarrow \Omega$, ohms, create heat

$C \rightarrow F$, Farad, store electro<u>static</u> energy

$L \rightarrow H$, Henry, store electro<u>magnetic</u> energy

Resistance

A resistor is passive and stores no energy in our simplified model of linear, lumped parameter, time invariant.

So when asking circuit questions – always obey the Passive Sign Convention.

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

Ohm's Law

Georg Simon Ohm – largely "home schooled" - just like any good engineer he embraced "life long learning".

Ohm's law is the algebraic relationship between voltage and current published in 1827 in *The Galvanic Circuit Investigated mathematically.*

$$v = iR$$

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

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

Conductance

A corollary concept is *Conductance* – the capacity for current flow.

Conductance is the reciprocal of resistance.

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

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

$$i = vG$$

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

Ideal Resistor

The ideal resistor's value does not change with varying circuit parameters such as temperature, current flow, voltage across it, or aging of the materials.

There is no such thing as the ideal resistor.

But we will assume ideal resistors in this introductory course anyway.

Power in a Resistor

Power is defined as $p = (\pm)vi$

The +/- is determined by current direction with respect to (wrt) the defined voltage across the resistor.

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

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

The resistor "only gets hot". Any other result in the resistor power calculation means you made a concept/definition error!

Section 2.4
Kirchhoff's Law

Solving Circuits

We have "solved" a circuit when we know the voltage and current of each circuit element.

Very often the solution is a set of equations – given some input (stimulus) values, we can then determine the output (response) of the circuit.

Gustav Kirchhoff first stated the basis for these sets of equations in 1848.

KCL

Kirchhoff's current law (KCL)

$$\sum_{n=1}^{\infty} i_n = 0$$

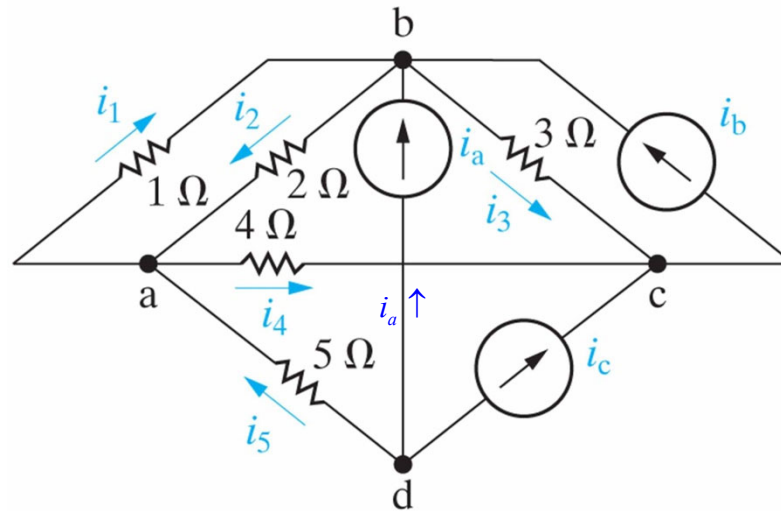The sum of all currents at a node equals zero.

Or as a physicist would say – conservation of charge – all current sources and current "sinks" accounted for.

Example 2.6

KCL convention:
    in = -
    out = +

At node d:

$$\sum_{n=1}^{\infty} i_n(node\ d) = 0 \rightarrow i_a + i_c + i_5 = 0$$
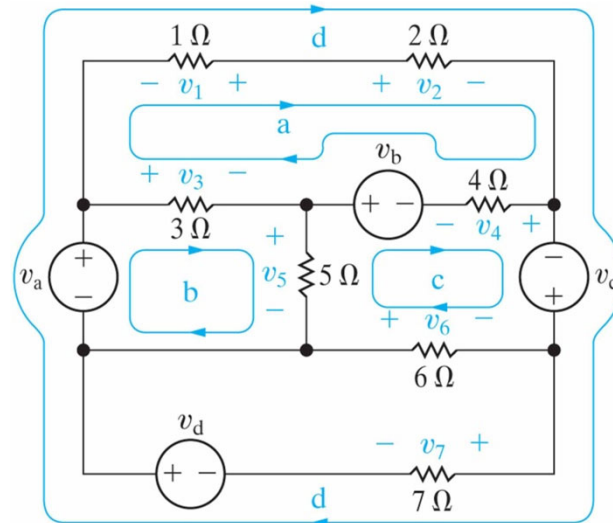
KVL

Kirchhoff's voltage law (KVL)

$$\sum_{n=1}^{\infty} v_n = 0$$

The sum of all voltages around any *closed* path equals zero.

Or as a physicist would say – conservation of energy – no net change in the energy of a system after one round trip.

Example 2.7

KVL – polarity reference pre-defined and written in order of moving through the loop.

For loop a

$$\sum_{n=1}^{\infty} v_n (loop\ a) = 0 \rightarrow -v_1 + v_2 + v_4 - v_b - v_3 = 0$$

Section 2.5
Analysis of a Circuit Containing Dependent Sources

Dependent Sources are hard

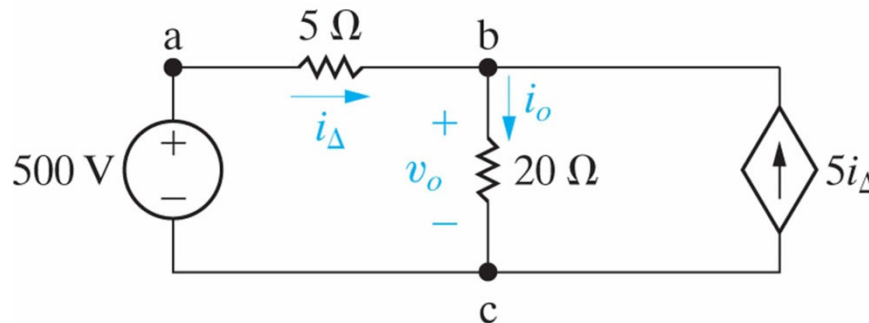At this point in your studies, dependent sources will be hard.

By their very definition, you must find a set of equations that obey the relationship demanded by the dependent source.

This is usually a multi-step process that simultaneously requires circuit insight and solid math skills.

You have the math skills – working problems will give you the insight.

Example

Find the current and voltages in the following circuit.

KCL at node b:

$$-i_\Delta + i_0 - 5i_\Delta = 0 \qquad \Rightarrow i_0 = 6i_\Delta$$

KVL for left hand loop

$$-500V + (5\Omega)i_\Delta + (20\Omega)i_0 = 0 \qquad \Rightarrow -500V + (5\Omega)i_\Delta + (20\Omega)(\underbrace{6i_\Delta}_{=i_0}) = 0$$

$$\Rightarrow (125\Omega)i_\Delta = 500V \qquad \Rightarrow i_\Delta = 4A$$

Thus $i_0 = 6(4) = 24A$ $v_0 = 20(24) = 480V$ $v_{5\Omega} = 5(4) = 20V$

Note that KVL (sum voltage = zero) is thus confirmed for this circuit.

Ideal Voltage Source – maintains the set voltage regardless of the current demanded by the external circuit.

Ideal Current Source – maintains the set current regardless of the voltage demanded by the external circuit.

Dependent Source – value of the output is a function of some circuit parameter.

Ideal Resistor – obeys Ohm's law regardless of temperature, voltage or current or any other material factor.

$$v = iR$$

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

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