ENGR 065 reference sheet

Tyler Armstrong

Fall 2021

Chapter 1: Circuit Variables

1.2: International System of Units

TABLE 1.3 Standardized Prefixes to Signify Powers of 10

Prefix	Symbol	Power
atto	a	10^{-18}
femto	f	10^{-15}
pico	p	10^{-12}
nano	n	10^{-9}
micro	μ	10^{-6}
milli	m	10^{-3}
centi	c	10^{-2}
deci	d	10^{-1}
deka	da	10
hecto	h	10^{2}
kilo	k	10^{3}
mega	M	10^{6}
giga	G	10^{9}
tera	T	10^{12}

Quantity	Unit Name (Symbol)	Formula
Frequency	hertz (Hz)	s^{-1}
Force	newton (N)	$kg \cdot m/s^2$
Energy or work	joule (J)	$N \cdot m$
Power	watt (W)	J/s
Electric charge	coulomb (C)	$A \cdot s$
Electric potential	volt (V)	J/C
Electric resistance	ohm (Ω)	V/A
Electric conductance	siemens (S)	A/V
Electric capacitance	farad (F)	C/V
Magnetic flux	weber (Wb)	$V \cdot s$
Inductance	henry (H)	Wb/A

Quantity	**Basic Unit**	**Symbol**
Length	meter	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	degree kelvin	K
Amount of substance	mole	mol
Luminous intensity	candela	cd

1.4 Voltage and Current

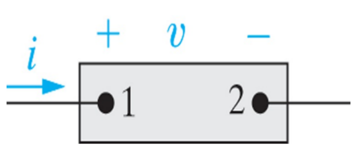
Definition of Voltage: $v = \frac{dw}{dq'}$	Definition of Current: $i = \frac{dq}{dt'}$
$v =$ the voltage in volts	$i =$ the current in amperes
$w =$ the energy in joules	$q =$ the charge in coulombs
$q =$ the charge in coulombs	$t =$ time in seconds

1.5 The Ideal Basic Circuit Element

The 3 attributes of an **ideal basic circuit element**.

1. It has only two terminals, which are points of connection to other circuit components.
2. It is described mathematically in terms of current and/or voltage.
3. It cannot be subdivided into other elements.

Passive Sign Convention:

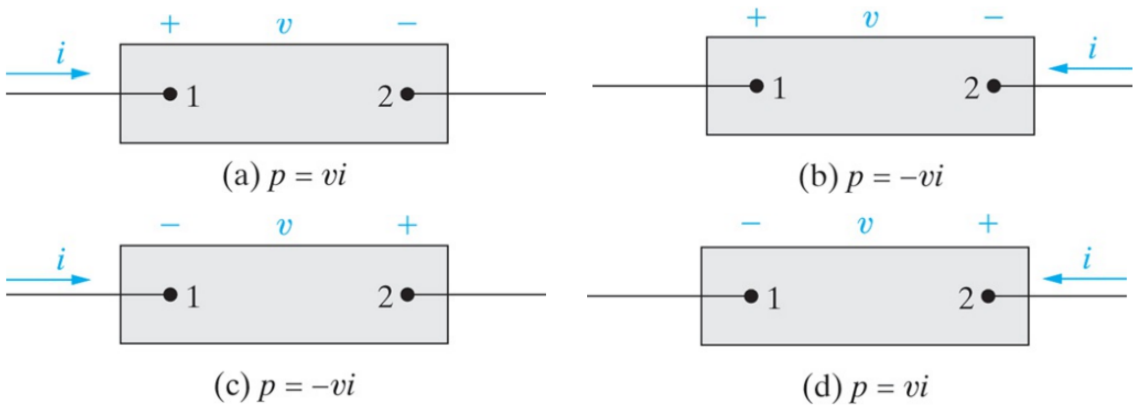


Ideal basic circuit element

	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 1 to terminal 2
i	+ charge flowing from terminal 1 to terminal 2 *or* - charge flowing from terminal 2 to terminal 1	+ charge flowing from terminal 1 to terminal 2 *or* - charge flowing from terminal 1 to terminal 2

1.6 Power and Energy

Definition of Power: $v = \dfrac{dw}{dt'}$	Power Equation: $p = vi$
$p =$ the power in watts	$p =$ the power in watts
$w =$ the energy in joules	$v =$ the voltage in volts
$t =$ the time in seconds	$i =$ the current in amperes



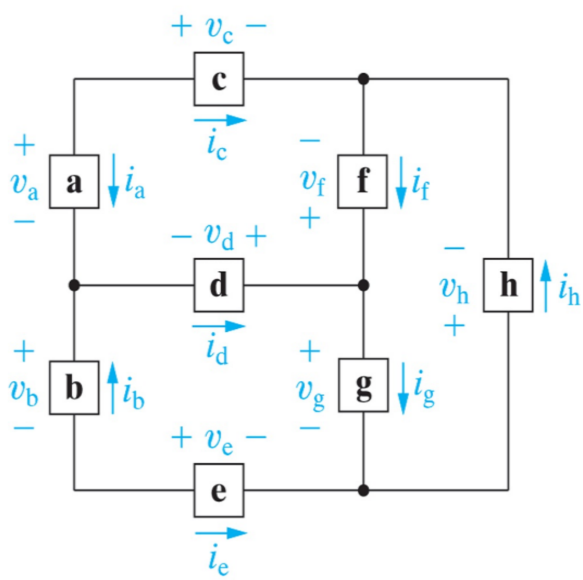
Balancing Power

$p > 0$: Power is being delivered.
$p < 0$: Power is being absorbed.

Delivering	Absorbing
$P_a = v_a i_a$	$P_b = -v_b i_b$
$P_c = v_c i_c$	$P_d = -v_d i_d$
$P_e = v_e i_e$	$P_f = -v_f i_f$
$P_g = v_g i_g$	
$P_h = v_h i_h$	

$P_{delivered} = P_{absorbed}$

If $P_{delivered} \neq P_{absorbed}$ something went wrong.

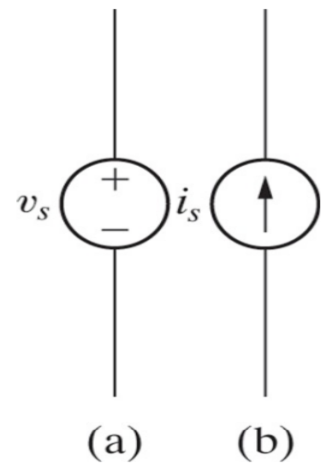


Chapter 2: Circuit Elements

2.1: Voltage and Current Sources

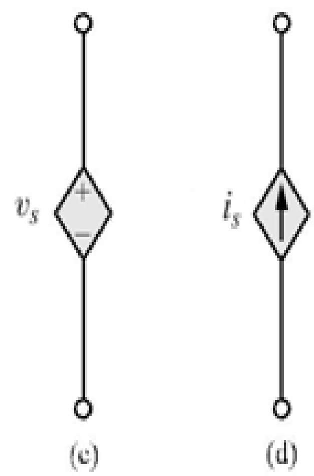
Independent Source(a,b)	A voltage or current in a circuit without relying on voltages or currents elsewhere in the circuit. The value of the voltage or current supplied is specified by the value of the independent source alone.
Dependent Source(c,d)	A voltage or current whose value depends on the value of a voltage or current elsewhere in the circuit. You cannot specify the value of a dependent source unless you know the value of the voltage or current on which it depends.

Ideal Voltage Source(a)	A circuit element that maintains a prescribed voltage across its terminals regardless of the current flowing in those terminals.
Ideal Current Source(b)	A circuit element that maintains a prescribed current through its terminals regardless of the voltage across those terminals.



	Dependence	Formula
Ideal Dependent Voltage Source(c)	Voltage	$v_s = \mu v_x$
v_s	Current	$v_s = \rho i_x$
Ideal Dependent Current Source(d)	Voltage	$i_s = \alpha v_x$
i_s	Current	$i_s = \beta i_x$

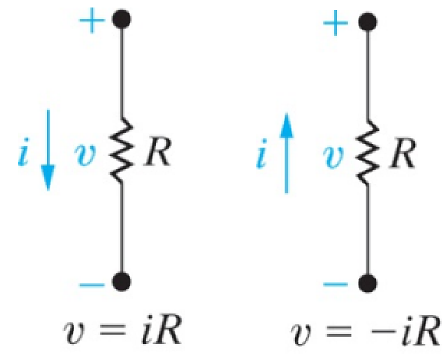
*note μ and β are dimensionless constants but ρ has dimensions volts per ampere $\frac{V}{A}$ and α has dimensions amperes per volt $\frac{A}{V}$



Active elements are those capable of generating electric energy.
Active Elements: Batteries, Generators, ect.
Passive elements are those that cannot generate electric energy.
Passive Elements: Resistors, Inductors, Capacitors ect.

2.2: Electrical Resistance (Ohm's Law)

Ohm's Law:	Formula & variants
$v =$ the voltage in volts	$v = iR$
$i =$ the current in amperes	$i = \frac{v}{R}$
$R =$ the resistance in ohms	$R = \frac{v}{i}$

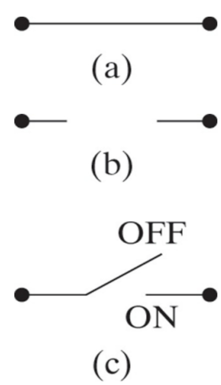


Power in Resistor in terms of:	Formulas
Voltage: v	$p = \frac{v^2}{R}$
Current: i	$p = i^2R$

2.3: Constructing a Circuit Model

Circuit Part	**Resistance**
Short Circuit(a)	$R = 0$
Open Circuit(b)	$R = \infty$
Switch(c)	$R = 0$ or $R = \infty$

*note assume ideal conditions



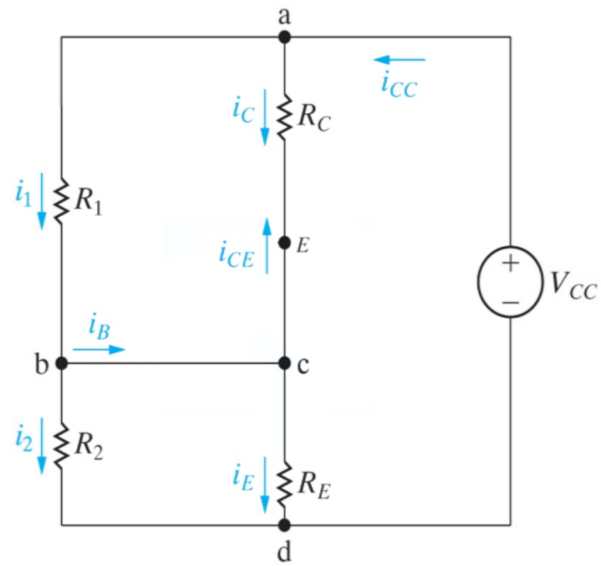
2.4: Kirchhoff's Laws

A **node** is a point where two or more circuit elements meet.

Law	**States**
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 voltages around any closed path in a circuit equals zero.

KCL Example:

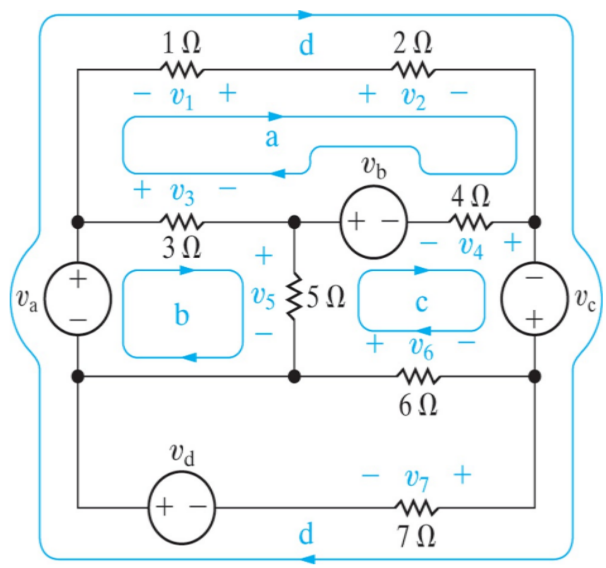
Node	Formula
a	$i_{CC} - i_C - i_1 = 0$
b	$i_1 - i_B - i_2 = 0$
c	$i_B + i_C - i_E = 0$
d	$i_2 + i_E - i_{CC} = 0$
e	$i_C + i_{CE} = 0$



KVL Example:

Loop	Formula
a	$-v_1 + v_2 + v_4 - v_b - v_3 = 0$
b	$-v_a + v_3 + v_5 = 0$
c	$v_b - v_4 - v_c - v_6 - v_5 = 0$
d	$-v_a - v_1 + v_2 - v_c + v_7 - v_d = 0$

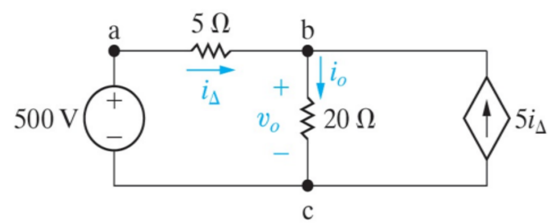
*note no loop needed in $v_d, 6\Omega$, and 7Ω space since all elements are already contained in loops c and d.



KCL & KVL Dependent Source Example:

Find unknowns: i_Δ, i_o, and v_o

Operation	Work
KCL	$-i_\Delta + i_o - 5i_\Delta = 0 \Rightarrow i_o = 6i_\Delta$ (1)
KVL	$-500 + 5i_\Delta + 20i_o = 0$ (2)
(1) $\rightarrow$ (2)	$500 = 5i_\Delta + 20(6i_\Delta) \Rightarrow i_\Delta = 4\text{A}$ (3)
(3) $\rightarrow$ (1)	$i_o = 6(4\text{A}) \Rightarrow i_o = 24\text{A}$ (4)
Ohm's Law	$v = iR \Rightarrow v_o = 20i_o$
(4) $\Rightarrow$ Ohm's	$v_o = 20(24\text{A}) \Rightarrow v_o = 480\text{V}$



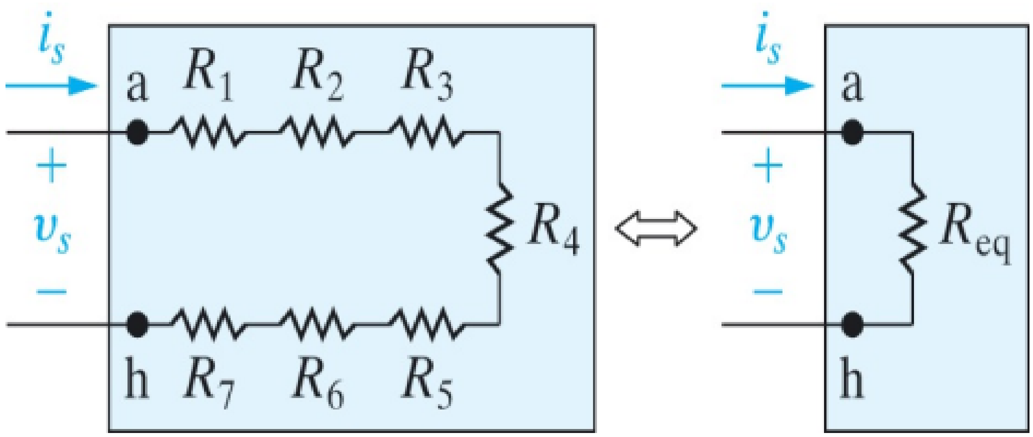
Chapter 3: Simple Resistive Circuits

3.1: Resistors in Series

Combining Resistors in Series:

The resistance of the equivalent resistor is always larger than the largest resistor in the series connection.
Current is shared between resistors in series.

$$R_{eq} = \sum_{i-1}^{k} R_i = R_1 + R_2 + \cdots + R_k$$

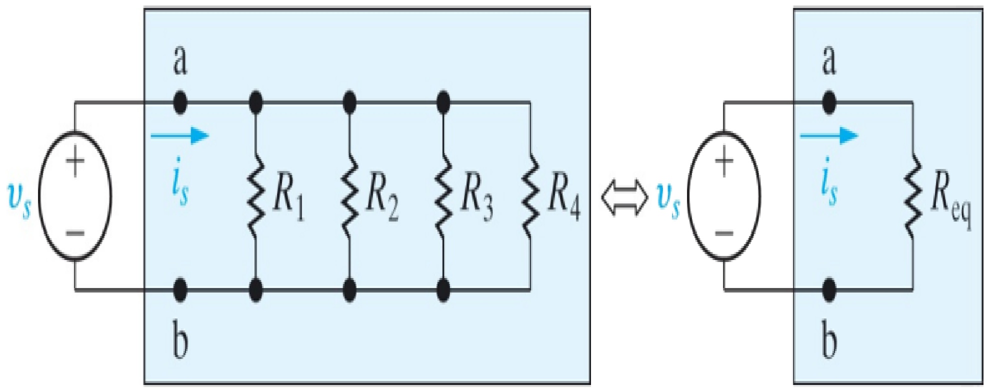


$$v_s = i_s(R_1 + R_2 + R_3 + R_4 + R_5 + R_6 + R_7)$$
$$R_{eq} = R_1 + R_2 + R_3 + R_4 + R_5 + R_6 + R_7$$
$$v_s = i_s R_{eq}$$

3.2: Resistors in Parallel

Combining Resistors in Parallel:
The resistance of the equivalent resistor is always smaller than the resistance of the smallest resistor in the parallel connection.
Voltage is shared between resistors in parallel.

$$\frac{1}{R_{eq}} = \sum_{i-1}^{k} \frac{1}{R_i} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_k}$$



$$i_s = v_s\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R_5} + \frac{1}{R_6} + \frac{1}{R_7}\right)^{-1}$$

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R_5} + \frac{1}{R_6} + \frac{1}{R_7}$$

$$i_s = v_s\left(\frac{1}{R_{eq}}\right)^{-1}$$

Combining Two Resistors in Parallel:

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{R_2 + R_1}{R_1 R_2}$$

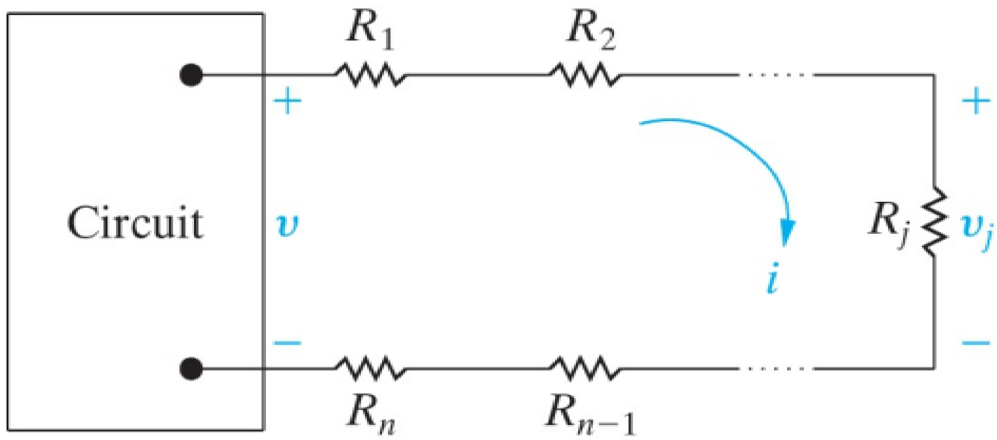
$$R_{eq} = \frac{R_1 R_2}{R_2 + R_1}$$

$$i_s = v_s R_{eq}$$

3.3: The Voltage-Divider and Current-Divider Circuits

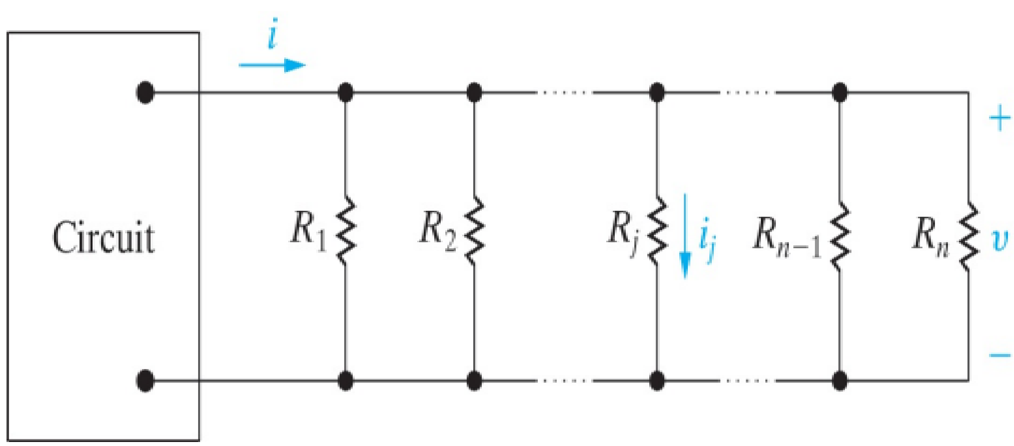
Voltage Division Equation:

$$v_j = iR_j = \frac{R_j}{R_{eq}}v$$



Current Division Equation:

$$i_j = \frac{v}{R_j} = \frac{R_{eq}}{R_j}i$$



3.6: Measuring Resistance - The Wheatstone Bridge

$$R_x = \frac{R_2}{R_1} R_3$$