ELECTRIC CIRCUITS
ECSE-2010
PROF. SHAYLA SAWYER

Lecture 1.1

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COMMON SYMBOLS & UNITS

Quantity	Symbol	Unit
Time	t	seconds (s)
Frequency	f	hertz (Hz)
Radian Frequency	ω	radians/sec (rad/s)
Energy	w	joules (J)
Power	p	watts (W)
Charge	q	coulombs (C)
Current	i	amperes (A)
Voltage	v	volts (V)

LECTURE 1.1 AGENDA

- Symbols and Units
- Circuit Variables
- Passive Sign Convention
- Voltage Reference Point – Ground

COMMON PREFIXES

		I	V	P
10^{12}	Tera	TA	TV	TW
10^{9}	Giga	GA	GV	GW
10^{6}	Mega	MA	MV	MW
10^{3}	kilo	kA	kV	kW
10^{0}	---	A	V	W
10^{-3}	milli	mA	mV	mW
10^{-6}	micro	uA	uV	uW
10^{-9}	nano	nA	nV	nW
10^{-12}	pico	pA	pV	pW

SYMBOLS & UNITS

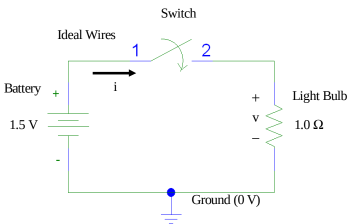
- Will Use International System (SI) of Units:
- 6 Fundamental Units in SI:
- meter (m), kilogram (kg), second (s), ampere (A), kelvin (K), candela (cd)
- All Other Units derived from these
- See Tables 1-1 and 1-2 in Text

CONSISTENT SETS OF UNITS

I (current)	V (voltage)	P (power)
A	V	W
mA	V	mW
A	mV	mW
uA	kV	mW
etc.		

CIRCUIT MODELS

- Never Solve a Real Circuit:
  - Solve Circuit Model
- Consider a Flashlight:
  - Battery, Bulb, Connections, Switch, Case
- Model for Battery: Ideal Voltage Source
  - Battery is a DC (Direct Current) Voltage Source
- Model for Connections: Ideal Wires
  - No Energy Loss
- Model for Bulb: Ideal Resistor
  - Linear Relationship between Current and Voltage



MODEL FOR FLASHLIGHT

Using PSpice

Circuit Variables
- Current (i)
- Voltage (v)
- Power (p)

Passive sign convention

Ground

CURRENT

- Current = i = Flow of Charge:

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

- Units of i = coulombs/sec = amperes (A)
- Current has Magnitude and Direction
- Direction of Current Arrow = Direction Positive Charge Would Flow +⟶-
- Current Flows in a Complete Path
- Assume Direction of i
- If i > 0 => Correct Assumption
- If i < 0 => Current Flows Other Way

VOLTAGE

- Voltage = v = Electrical Potential Energy Difference/Unit Charge => Potential Difference

$$v = \frac{dw}{dq}$$

- Potential Difference Drives Charge
- Units of v = joules/coulomb = volts (V)
- Must define positive (+) and negative (-) terminals for voltage
- Will use Passive Convention to do this
- Assume polarity for v; Calculate v
- If v < 0, then the terminals are reversed

POWER

- Power = p = Electrical Energy/Time

$$p = \frac{dw}{dt} = \left(\frac{dw}{dq}\right)\left(\frac{dq}{dt}\right) = v\,i$$

- Units of p = joules/sec = watts (W)
- Circuit Elements may Absorb or Supply Power

ENERGY

- Energy = w = Electrical Energy

$$w = \int p\,dt$$

- Units of w = watt-sec (commonly kW-hr)
- Circuit Elements may Absorb or Supply Energy
- Will use Power More Frequently than Energy

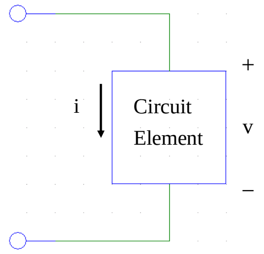
PASSIVE CONVENTION

- Passive Convention Assumes Current (i) Flows from + to - in a Circuit Element:
- We Will Assume the Passive Convention for All Circuit Elements:
- Can Assume a Polarity for Voltage (v):
- Passive Convention Determines Direction of Current (i)
- OR: Assume Direction for Current (i):
- Passive Convention Determines Polarity of Voltage (v)

PASSIVE CONVENTION

Initial assumption to provide reference point for the circuit

p = v i = Power Absorbed



Current flows from + to –

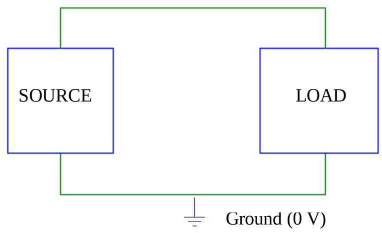
PASSIVE CONVENTION

- Define v and i using Passive Convention:
- p = v i = Power Absorbed:
- If p = v i > 0 => Element Absorbs Power
- If p = v i < 0 => Element Supplies Power
- If Element Absorbs Power => LOAD
- If Element Supplies Power => SOURCE

VOLTAGE REFERENCE POINT

- Voltage is Defined Between 2 Points in Circuit:
- Voltage Difference is What Drives Charge
- For Analysis, Can Always Choose Voltage at 1 Point as Reference
- Usually Assume Voltage at Reference Point is 0 Volts => GROUND

VOLTAGE REFERENCE POINT



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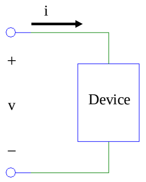
Lecture 1.2

LECTURE 1.2 AGENDA

- Circuits & Devices
- Linear Resistor – Ohm's Law
- Open/Short Circuits – Ideal Switches
- Ideal Voltage and Current Sources

CIRCUIT ELEMENTS

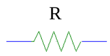


$p = v\,i$ = Power Absorbed by Device

Device described by plot of i vs. v (or v vs. i)

LINEAR RESISTOR

- A Linear Resistor is the Most Common Element Used in Circuits:
- Symbol = R
- Circuit Model =

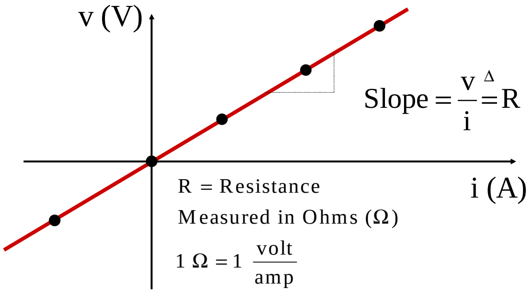


R = Resistance $= \frac{\rho L}{A}$ (for cylinder);

ρ = Resistivity of Material, L = Length,

A = Cross-sectional Area

LINEAR RESISTOR



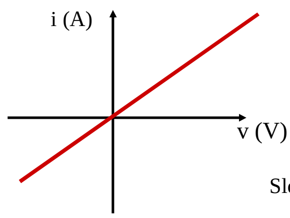
$\text{Slope} = \frac{v}{i} \triangleq R$

R = Resistance

Measured in Ohms (Ω)

$1\ \Omega = 1\ \frac{\text{volt}}{\text{amp}}$

LINEAR RESISTOR



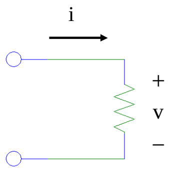
$\text{Slope} = \frac{i}{v} = \frac{1}{R} = G$

G =Conductance in Siemens (1/ohms)

OHM'S LAW

- Important Concept - Will Always Use
- Plot of v vs. i for Resistor is LINEAR
- Goes through v = 0, i = 0
- Slope of Line = v/i = R;
- Units of R: Ohms = volts/amp (Ω)
- Equation of Straight Line Thru Origin:
- => v = i R
- => Ohm's Law

OHM'S LAW



Ohm's Law

$$v = i\,R$$

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

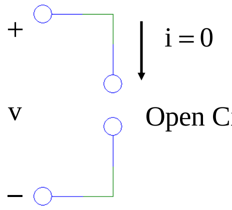
$$R = \frac{v}{i}$$

$$p = v\,i = (iR)(i) = i^2 R$$

$$= (v)(\frac{v}{R}) = \frac{v^2}{R}$$

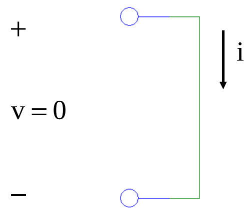
OPEN CIRCUIT

Equivalent to $R \to \infty$



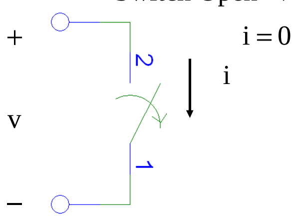
SHORT CIRCUIT

Equivalent to $R \to 0$



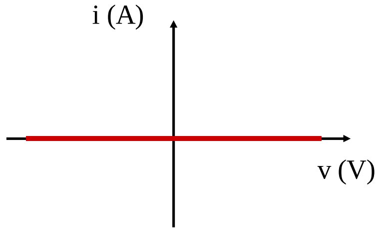
IDEAL SWITCH

Switch Open $\to$ Open Circuit



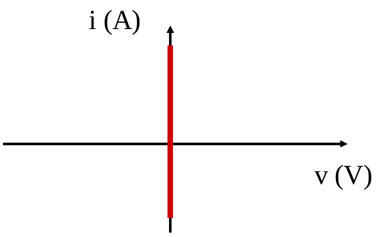
Switch Closed $\to$ Short Circuit

IDEAL SWITCH – OPEN



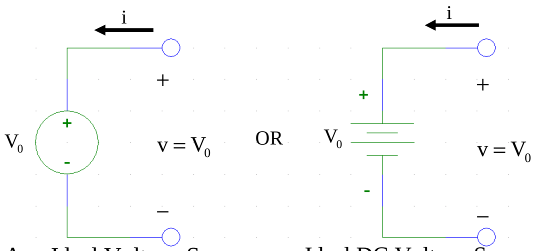
Open Switch $\to$ Open Circuit

IDEAL SWITCH - CLOSED



Closed Switch → Short Circuit

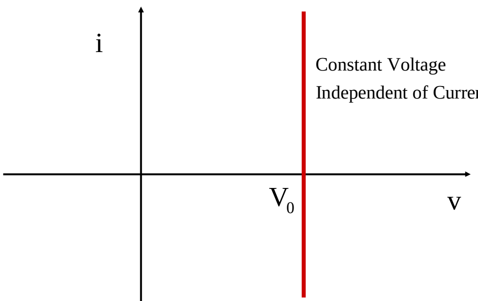
IDEAL VOLTAGE SOURCE



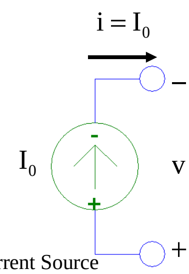
Any Ideal Voltage Source (DC, AC, etc)

Ideal DC Voltage Source (Battery)

IDEAL VOLTAGE SOURCE



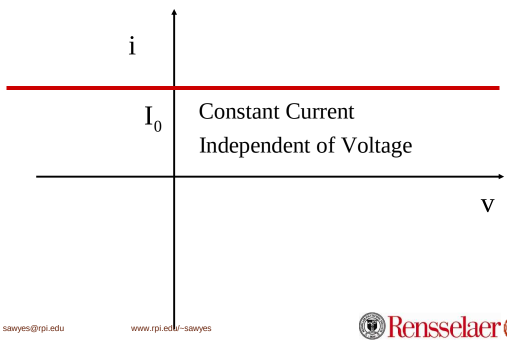
IDEAL CURRENT SOURCE



Any Ideal Current Source (DC, AC, etc)

No Special Symbol for DC

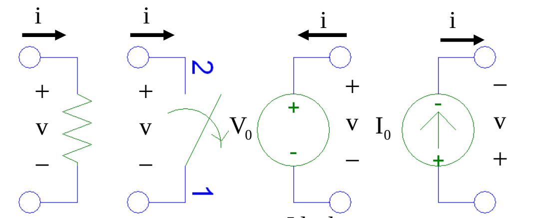
IDEAL CURRENT SOURCE



IDEAL SOURCES

- Ideal Voltage Source:
  - Model = Circle with + and - voltage terminals
  - Voltage always the same across voltage source
  - Can supply any current
  - Current through voltage source can be anything
- Ideal Current Source:
  - Model = Circle with Current Arrow
  - Current always the same from current source
  - Can supply any voltage
  - Voltage across current source can be anything

INITIAL CIRCUIT ELEMENTS



Resistor
$v = iR$

Ideal
Switch

Ideal
Voltage
Source

Ideal
Current
Source

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Lecture 1.3

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LECTURE 1.3 AGENDA

- Definitions
- Reference Marks
- Kirkoff's Laws
- Practice Problems

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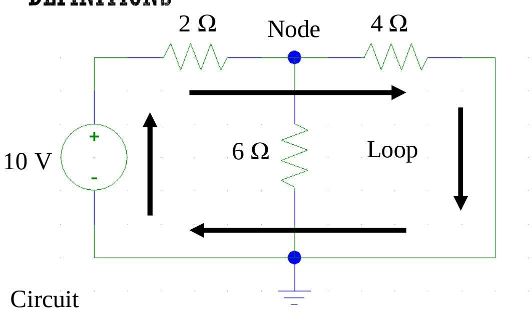
DEFINITIONS



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DEFINITIONS

- Circuit: Interconnection of electrical devices
- Node: Electrical juncture of 2 or more electrical devices
- Loop: Closed path formed by tracing through an ordered sequence of nodes without passing through any node more than once

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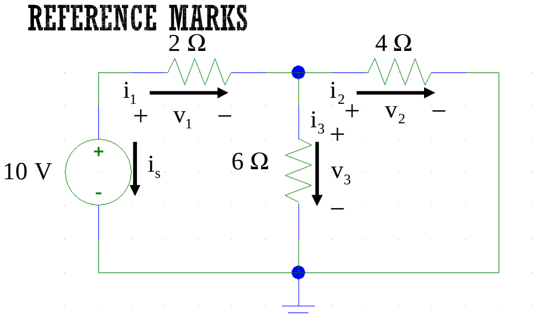
REFERENCE MARKS



Choose Direction for i's → Determines Polarity for v's

Always Use Passive Convention

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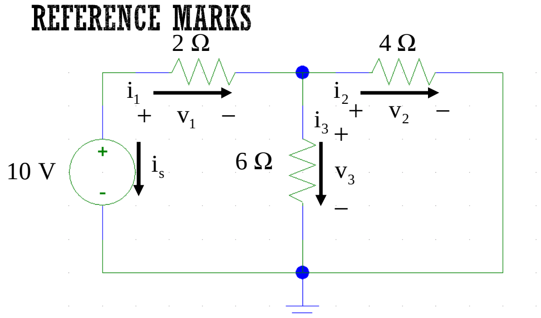
REFERENCE MARKS



OR: Choose Polarity for v's → Determines Direction for i's

Always Use Passive Convention

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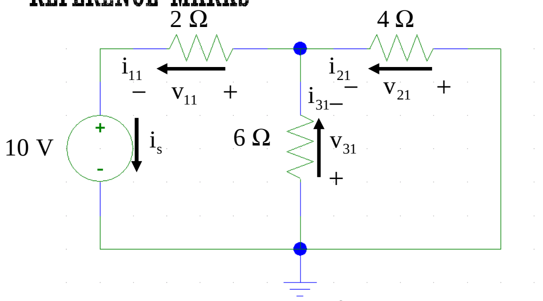
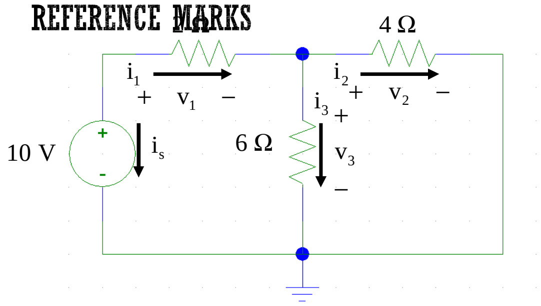
REFERENCE MARKS



Initial Choice is Arbitrary for Resistors

$i_{11} = -i_1,\ v_{11} = -v_1,$ etc.

REFERENCE MARKS



4 Unknown Currents: i_1, i_2, i_3, i_s

3 Unknown Voltages: v_1, v_2, v_3

KIRCHHOFF'S LAWS

- Based on Conservation Laws
- Conservation of Charge => KCL
  - Kirchhoff's Current Law
- Conservation of Energy => KVL
  - Kirchhoff's Voltage Law
- Can <u>ALWAYS</u> Rely on KCL, KVL
- Starting Point for Most Circuit Analysis – Will Use Again & Again

KIRCHHOFF'S LAWS

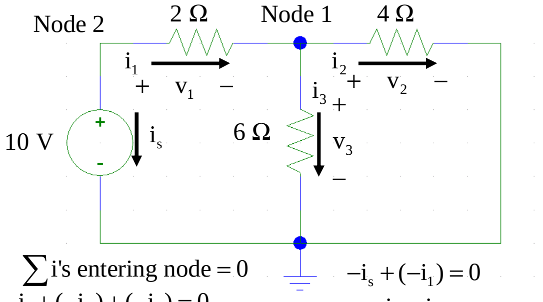
- Kirchhoff's Current Law:
- The algebraic sum of the currents entering a node is zero at every instant

$$\sum \text{i's entering a node} = 0$$

$$\text{OR:}\quad \sum \text{i's out of a node} = 0$$

$$\text{OR:}\quad \sum \text{i's entering a node} = \sum \text{i's out of a node}$$

KIRCHHOFF'S CURRENT LAW



$$\sum \text{i's entering node} = 0$$

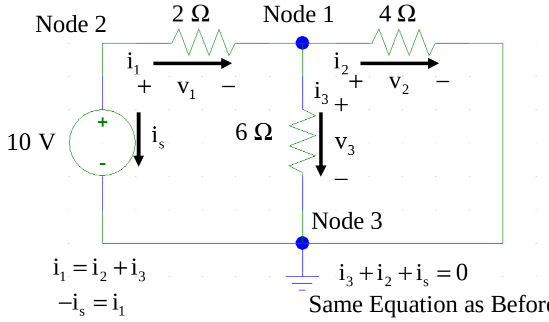
$$i_1 + (-i_2) + (-i_3) = 0$$

$$i_1 = i_2 + i_3$$

$$-i_s + (-i_1) = 0$$

$$-i_s = i_1$$

KIRCHHOFF'S CURRENT LAW



$$i_1 = i_2 + i_3$$

$$-i_s = i_1$$

$$-i_s = i_2 + i_3$$

$$i_3 + i_2 + i_s = 0$$

Same Equation as Before

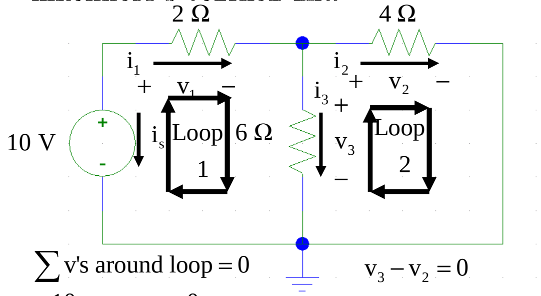
KIRCHHOFF'S LAWS

- Kirchhoff's Voltage Law:
- The algebraic sum of all the voltages around a loop is zero at every instant

$$\sum \text{v's around a loop} = 0$$

Can go around a loop in either direction

KIRCHHOFF'S VOLTAGE LAW



$$\sum \text{v's around loop} = 0$$

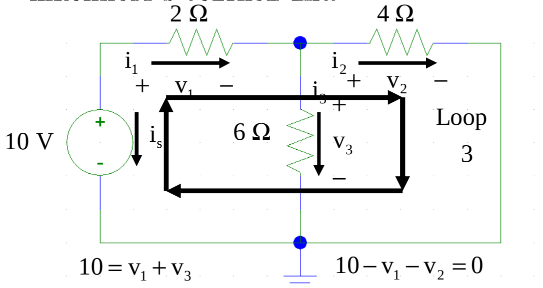
$$10 - v_1 - v_3 = 0$$

$$10 = v_1 + v_3$$

$$v_3 - v_2 = 0$$

$$v_2 = v_3$$

KIRCHHOFF'S VOLTAGE LAW



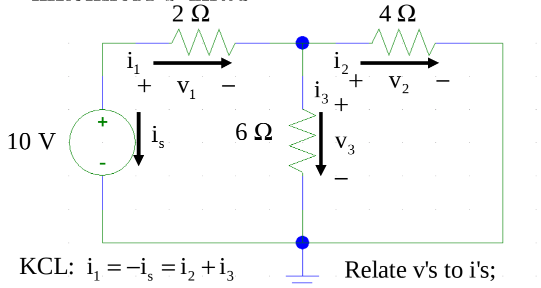
$$10 = v_1 + v_3$$

$$v_2 = v_3$$

$$10 - v_1 - v_2 = 0$$

No New Information

KIRCHHOFF'S LAWS



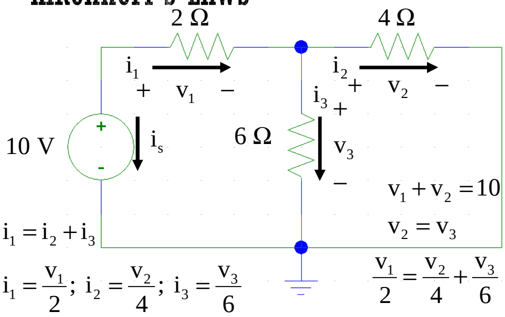
KCL: $i_1 = -i_s = i_2 + i_3$

KVL: $10 = v_1 + v_2;\ v_2 = v_3$

Relate v's to i's;

Use Ohm's Law

KIRCHHOFF'S LAWS



$$v_1 + v_2 = 10$$

$$v_2 = v_3$$

$$i_1 = i_2 + i_3$$

$$i_1 = \frac{v_1}{2};\ i_2 = \frac{v_2}{4};\ i_3 = \frac{v_3}{6}$$

$$\frac{v_1}{2} = \frac{v_2}{4} + \frac{v_3}{6}$$

KIRCHHOFF'S LAWS

$$v_1 + v_2 = 10$$

$$v_2 = v_3$$

$$\frac{v_1}{2} = \frac{v_2}{4} + \frac{v_3}{6}$$

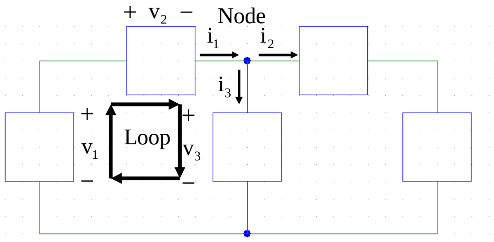
$$v_1 + v_2 = 10$$

$$6v_1 - 5v_2 = 0$$

$$v_1 = \frac{50}{11}\ \text{V};\ v_2 = \frac{60}{11}\ \text{V} = v_3$$

$$i_1 = \frac{50}{22}\ \text{A} = -i_s;\ i_2 = \frac{30}{22}\ \text{A};\ i_3 = \frac{20}{22}\ \text{A}$$

KIRCHHOFF'S LAWS



KCL: $i_1 = i_2 + i_3$ KVL: $v_1 = v_2 + v_3$

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