Circuit Analysis Techniques

Lecture 1
Circuit Elements

Lecture delivered by:

Topics

- Circuit elements
- Active elements
- Passive elements
- Voltage and current
- Resistance, capacitance and inductance
- Ohm’s law
- Kirchoff’s laws

Objectives

At the end of this lecture, student will be able to:

- Classify Circuit Elements
- Identify basic active and passive elements
- Define current, voltage, Resistance, Capacitance and inductance
- State and Illustrate Ohm’s law
- State and solve Kirchoff’s law

Introduction

- Circuit analysis is used to predict the behavior of the electrical circuits and play an important role in the design process.

Introduction

Why Study Electrical Engineering?

- To operate and maintain electrical systems
- To communicate with electrical engineering consultants
- To distribute and convert energy between various forms
- To design projects in your own field

What Do You Infer From This Figures?

cave

Hut

Building

What Do You Infer From This Figures?

Candle

Bulb

C F L

What do you infer from this figures?

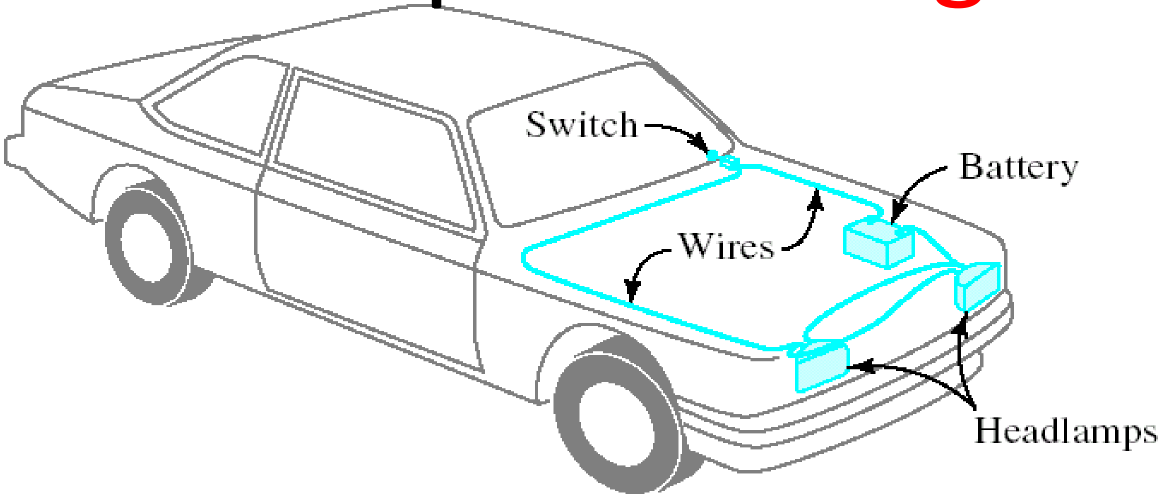
Walking man

Bike

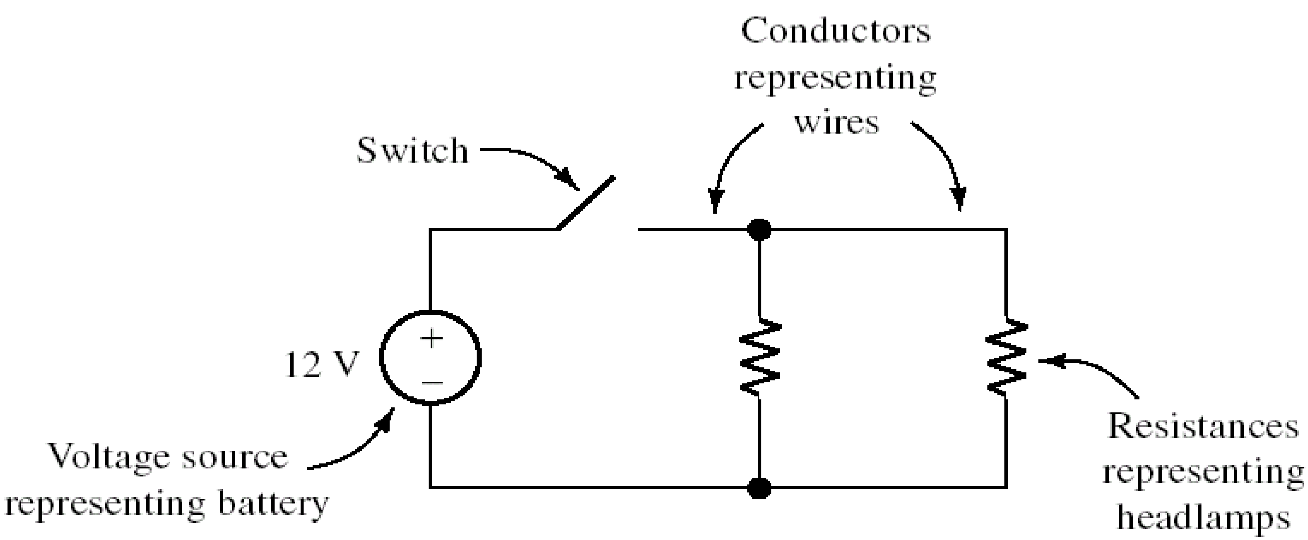
Car

Airplane

Application Example: Headlight Circuit



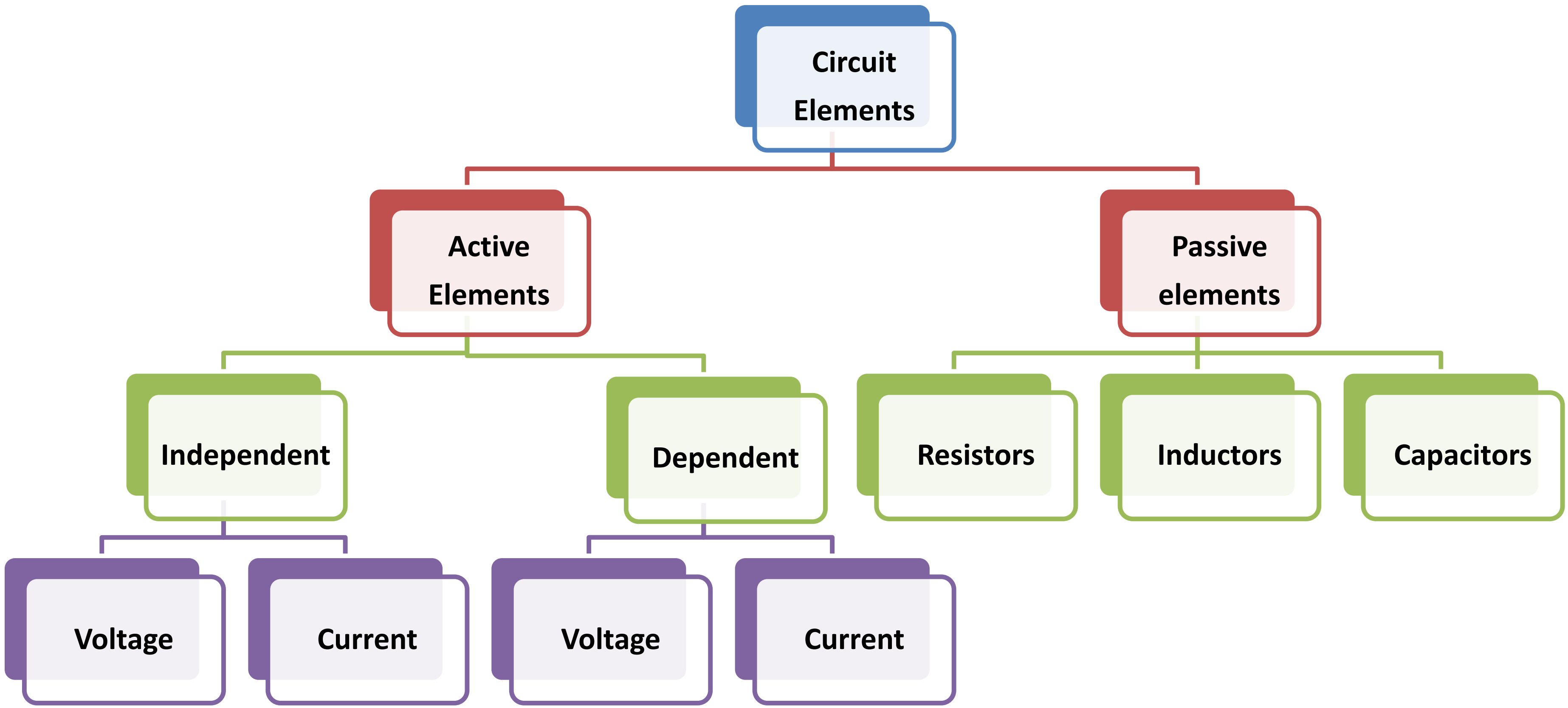
(a) Physical configuration



(b) Circuit diagram

Basic Circuit Elements

- Circuit elements mainly consists of active and passive elements and categorized as shown



Circuit Elements

- Active elements are capable of generating electrical energy
- Passive elements are incapable of generating electrical energy
- Electrical source is a device that is capable of converting non-electrical energy into electrical energy

Example: Battery

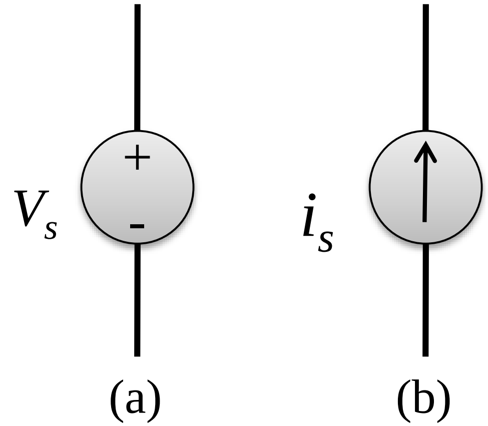
Generator

Active Element

- Sources is categorized as
  - ✓ **Independent sources** where generated voltage or current does not depend on the other circuit elements
  - ✓ **Dependent Sources** where the generated voltage or current depends on another circuit voltage or current

Active Element

- Independent voltage source provides a specified voltage
- Independent voltage source (or current source), the terminal voltage (or current) would depend only on the loading and the internal source quantity
- But not on any other circuit variable
- The circle is used as the circuit symbol for independent sources are as shown



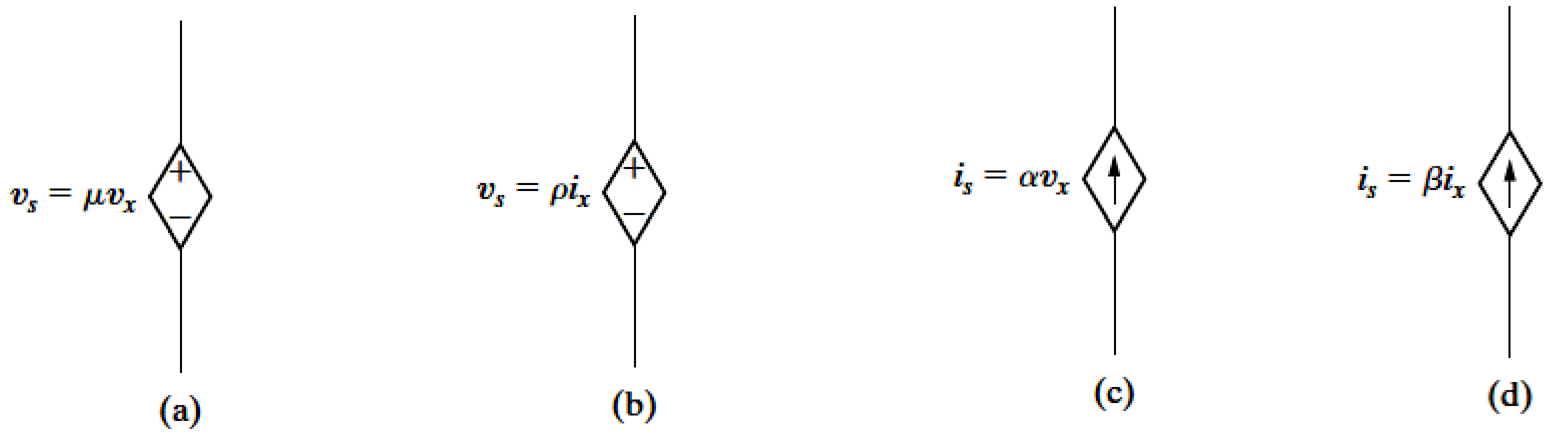
The circuit symbols for (a) an ideal independent voltage source and (b) an ideal independent current source

Active Element

- Dependent source is a voltage or current generator whose source quantity depends on another circuit variable (current or voltage)
- There are a total of four variations of dependent sources
  - VCVS, VCCS, CCVS, CCCS
- Dependent sources are also called **controlled sources**

Active Element

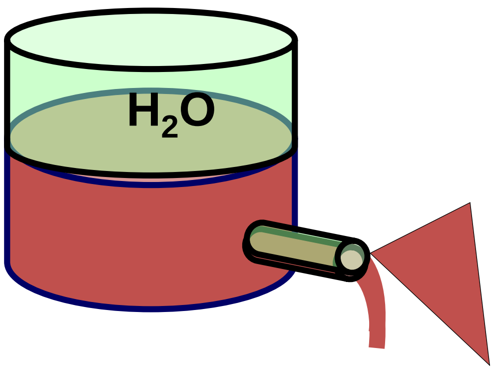
- Diamond is used to represent a dependent source



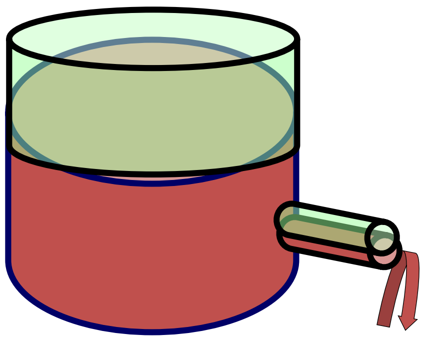
The circuit symbols for (a) voltage-controlled voltage source, (b) current-controlled voltage source, (c) voltage-controlled current source, and (d) current-controlled current source.

What is Voltage?

V = “Electrical pressure” - measured in ***volts.***



High Pressure



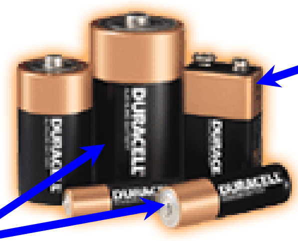
Low Pressure

What Produces Voltage?

V = “Electrical pressure”

A Battery

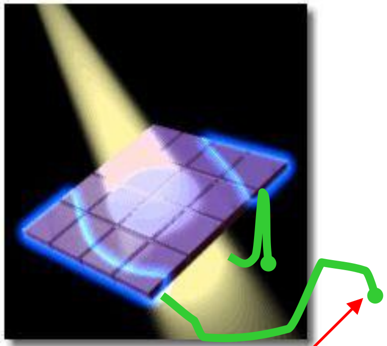
9 V



1.5 V

Lab Power Supply

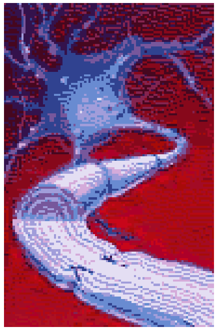
Solar Cell



A few Volts

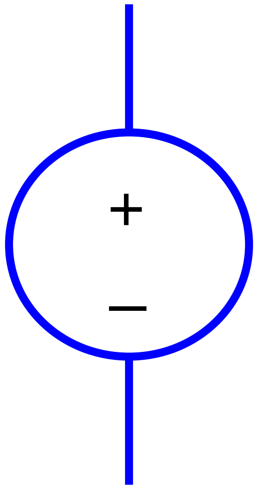
Electric Power Plant

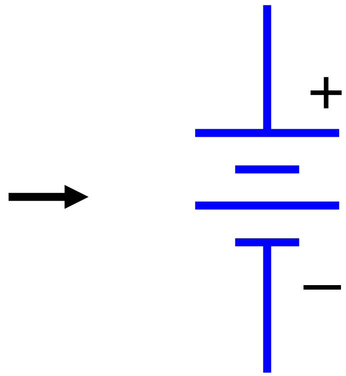
Nerve Cell



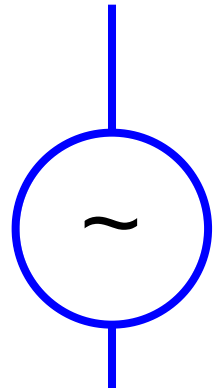
A few **millivolts** when activated by a synapse

- Other Symbols Used for Specific Voltage Sources

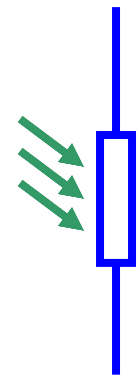




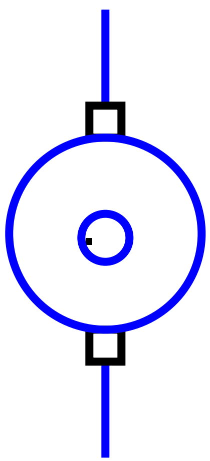
Battery



Time-varying source



Solar Cell



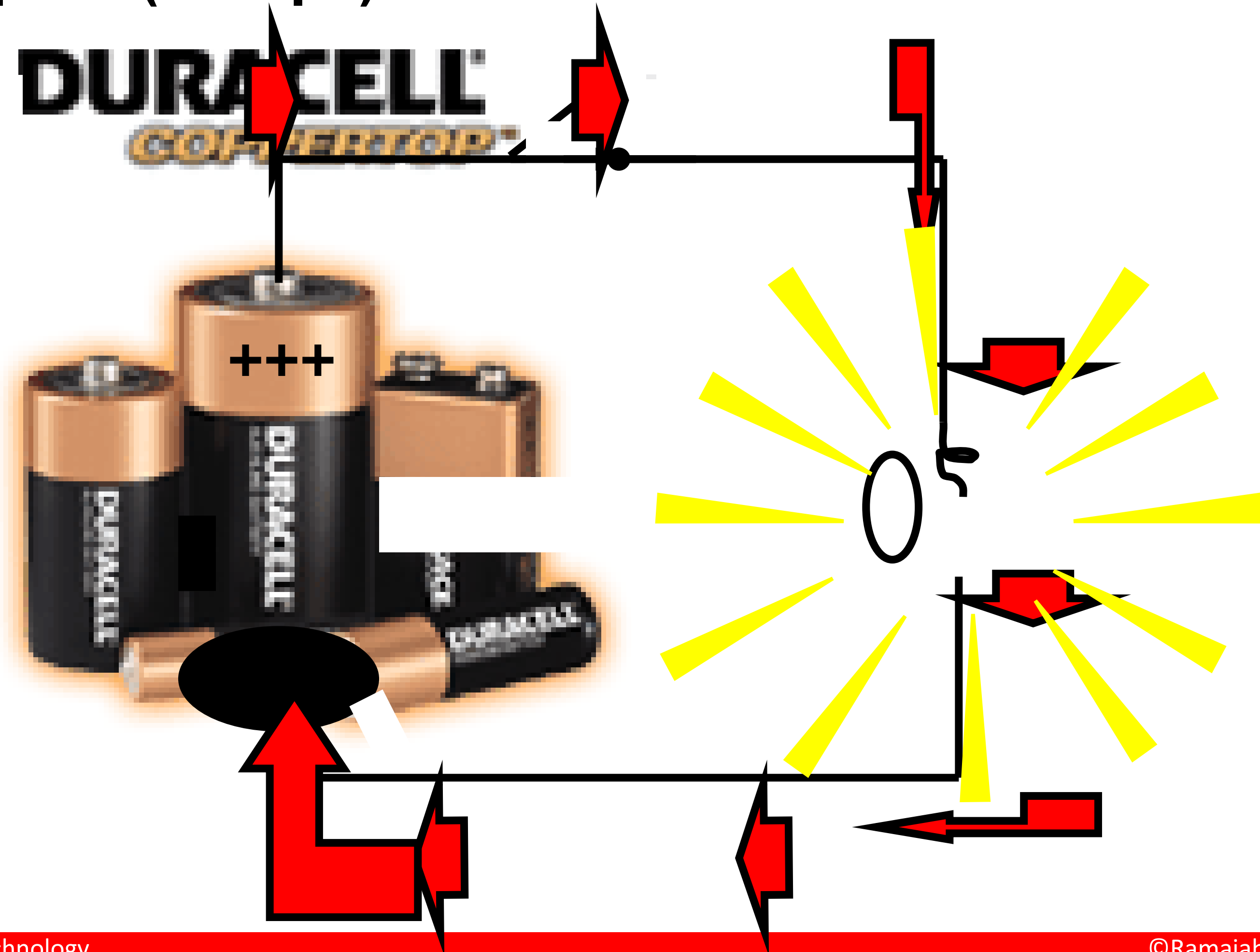
Generator (power plant)

These are all…

<u>Voltage Sources</u>

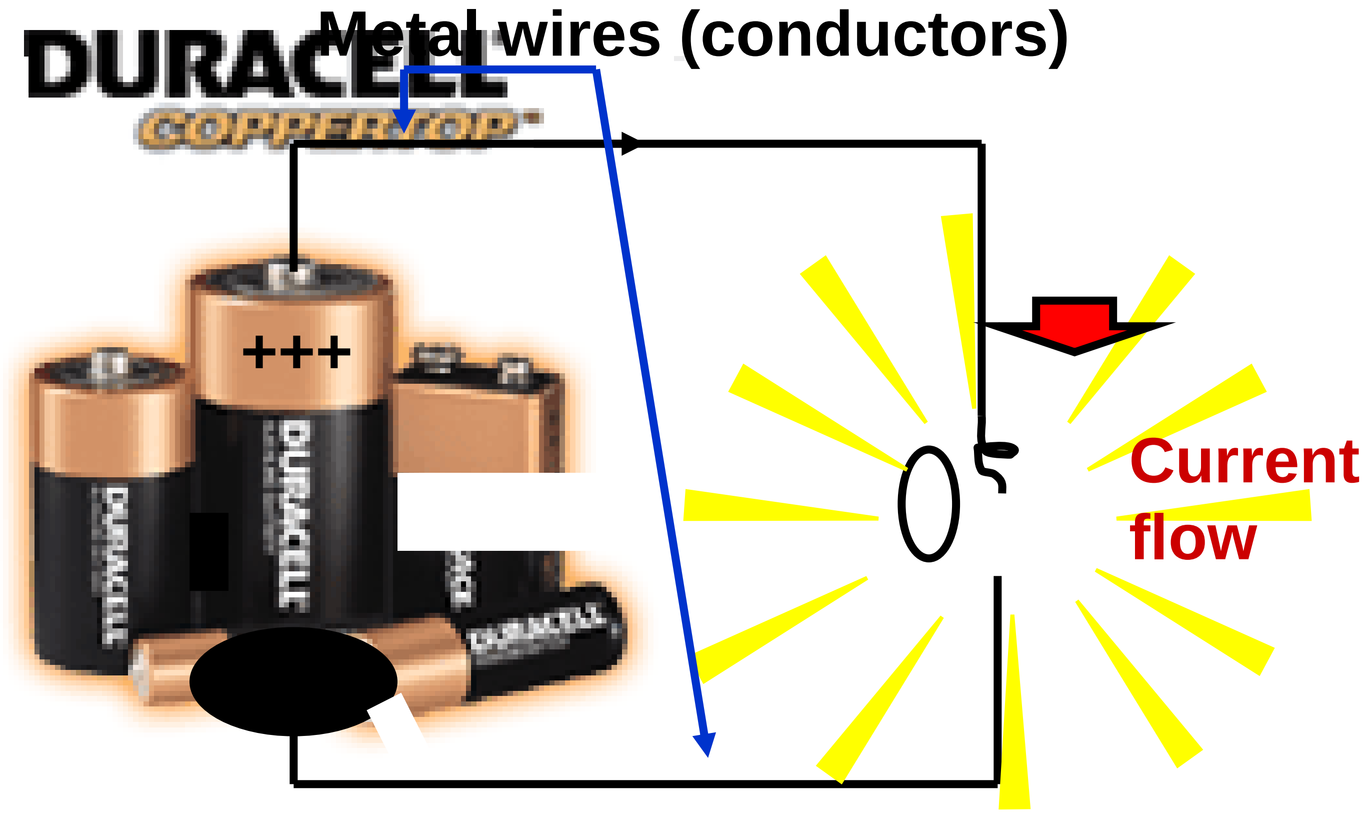
What is Current?

- Current is the flow of charge from a voltage source
- 1 Ampere ("Amp") = Flow of 1 Coulomb/sec



How Does Current Flow?

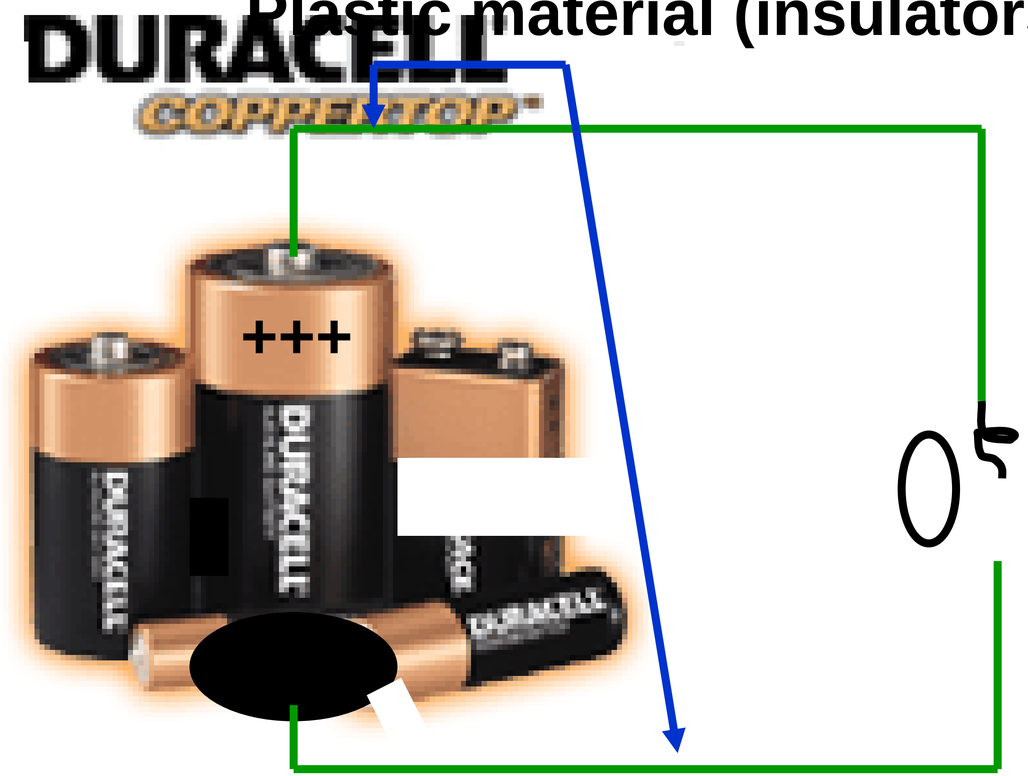
Current can only flow through conductors



When Does Current *NOT* Flow?

Current cannot flow through insulators

Plastic material (insulators)



No current flow

What is Current?

- **Electricity flows when electrons travel through a conductor.**
- **We call this flow "current."**
- **Only some materials have free electrons inside.**

YES!

Conductors:

silver
copper
gold
aluminium
iron
steel
brass
bronze
mercury
graphite
dirty water
concrete

NO!

Insulators:

glass
rubber
oil
asphalt
fiberglass
porcelain
ceramic
quartz
(dry) cotton
(dry) paper
(dry) wood
plastic
air
diamond
pure water

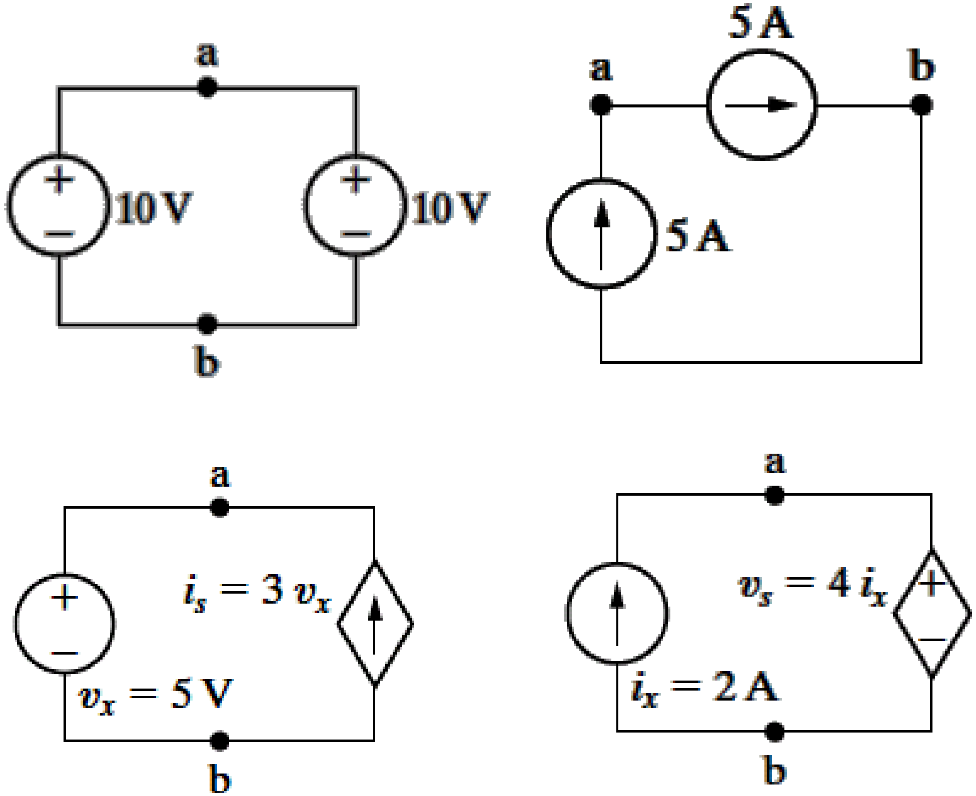
No free electrons = No current

Current and Voltage

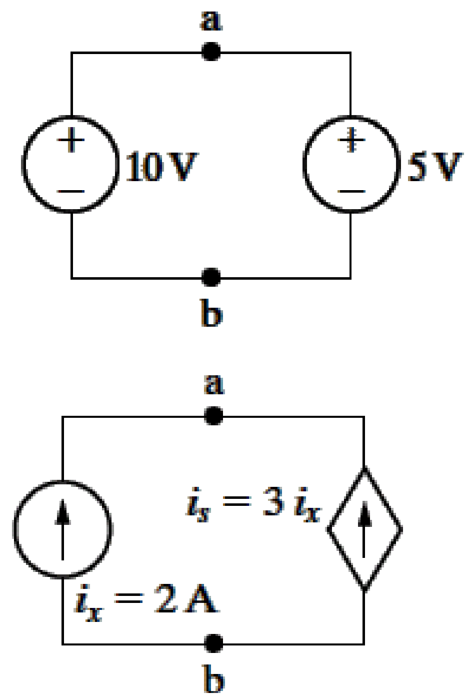
	Current	Voltage
Definition	Rate of flow of electric charge	Potential difference between two points in the circuit
Symbol	I	V
Units	A or Amps	V or Volts
Measuring Instrument	Ammeter	Voltmeter
Field created	Magnetic Field	Electrostatic Field
In series connection	Current is same through all components connected in series	Voltage over components connected in series gets distributed
In parallel connection	Current gets distributed over components when connected in parallel	Voltage is same over all the components when connected in parallel

Characteristics of Sources

Valid circuit



Invalid circuit

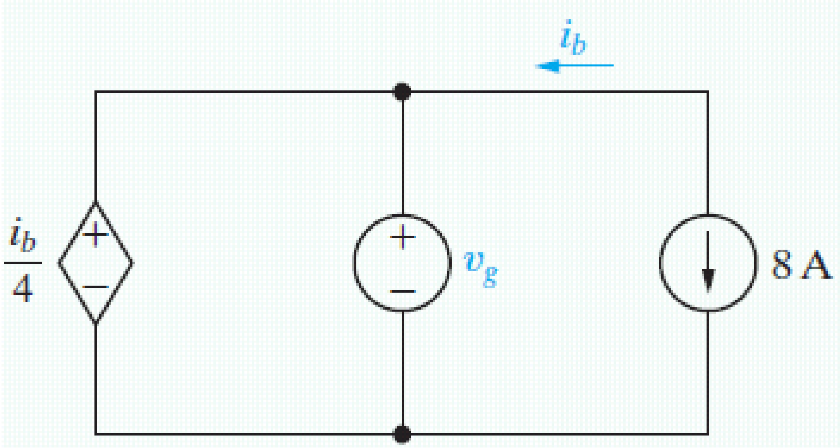


Solve

- For the circuit shown,

a) What value of v_g is required in order for the interconnection to be valid?

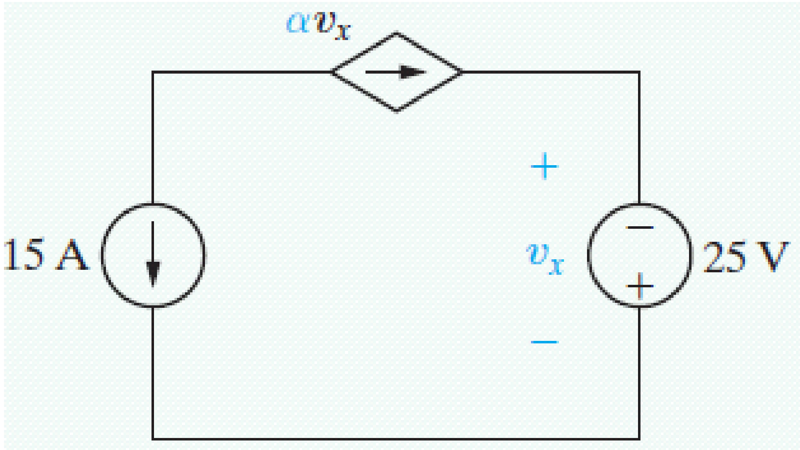
b) For this value of v_g, find the power associated with the 8 A source



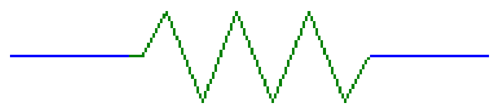
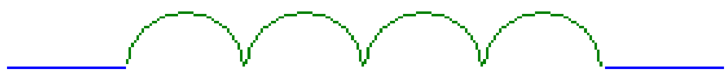
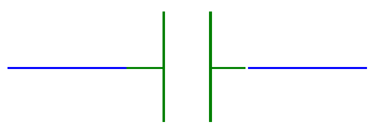
- For the circuit shown,

a) What value of α is required in order for the interconnection to be valid?

b) For the value of α calculated in part (a), find the power associated with the 25 V source

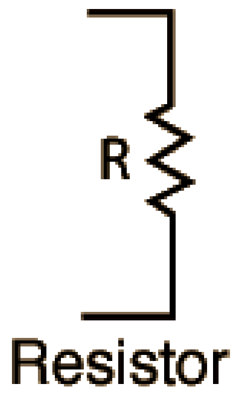


Passive Components

Component	Symbol	Basic Measure (Unit)
Resistor		Ohm (Ω)
Inductor		Henry (H)
Capacitor		Farad (F)

Resistance

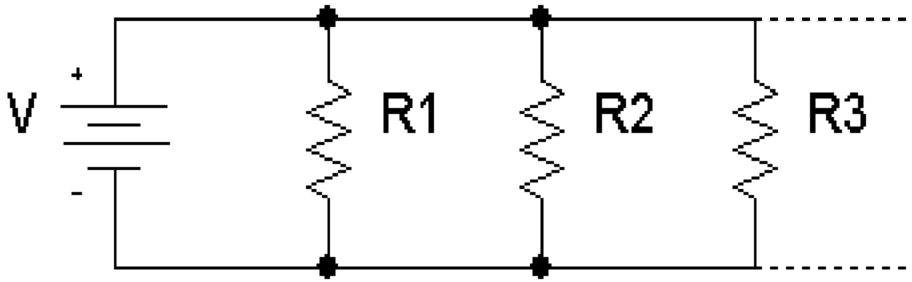
- Resistor is an electrical component that reduces the electric current.
- Resistor's ability to reduce the current is called resistance
- Unit of resistance is ohms (symbol: Ω)



$$R = \frac{V}{I}$$

Equivalent Resistance

- Resistors in parallel

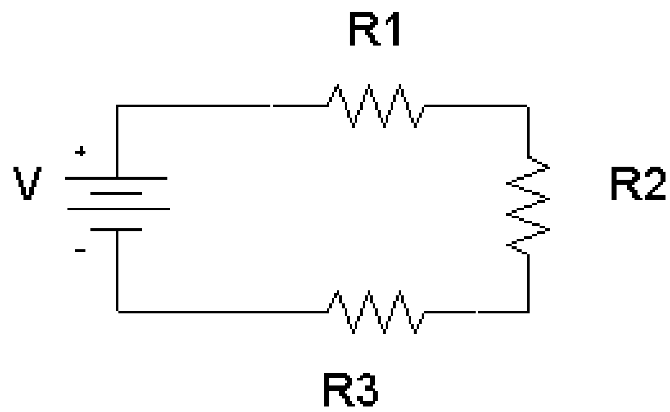


- Total resistance or equivalent resistance is given by

$$\frac{1}{R_{Total}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$$

Equivalent Resistance

- Resistors in series



- Total resistance or equivalent resistance is given by

$$R_{total} = R_1 + R_2 + R_3 + \ldots$$

- Value of resistance increases when connected in series

Resistor color code

- The resistance of the resistor and its tolerance are marked on the resistor with color code bands that denotes the resistance value.
- There are 3 types of color codes:
  I. 4 bands: digit, digit , multiplier, tolerance.
  II. 5 bands: digit, digit, digit , multiplier, tolerance.
  III. 6 bands: digit, digit, digit , multiplier, tolerance, temperature coefficient.

Resistor color code

- Resistance calculation of 4 band resistor is given by

$$R = (10 \times digit_1 + digit_2) \times multiplier$$

- Resistance calculation of 5 band and 6 band resistor is given by

$$R = (100 \times digit_1 + 10 \times digit_2 + digit_3) \times multiplier$$

Resistor Color Code Table

	1st Digit	2nd Digit	3rd Digit	Multiplier	Tolerance	Temperature Coefficient
4bands	1	2		3	4	
5bands	1	2	3	4	5	
6bands	1	2	3	4	5	6
Black	0	0	0	$\times 10^0$		
Brown	1	1	1	$\times 10^1$	±1%	100 ppm/ºK
Red	2	2	2	$\times 10^2$	±2%	50 ppm/ºK
Orange	3	3	3	$\times 10^3$		15 ppm/ºK
Yellow	4	4	4	$\times 10^4$		25 ppm/ºK
Green	5	5	5	$\times 10^5$	±0.5%	
Blue	6	6	6	$\times 10^6$	±0.25%	10 ppm/ºK
Violet	7	7	7	$\times 10^7$	±0.1%	5 ppm/ºK
Grey	8	8	8	$\times 10^8$	±0.05%	
White	9	9	9	$\times 10^9$		
Silver				$\times 10^{-2}$	±10%	
Gold				$\times 10^{-1}$	±5%	
None					±20%	

How to remember Color Codes ?

B **B** **R** **O** **Y** of **G**reat **B**ritain has **V**ery **G**orgeous **W**ife

Green Blue

Violet

Yellow

Gray

Orange

Red

White

Brown

Black

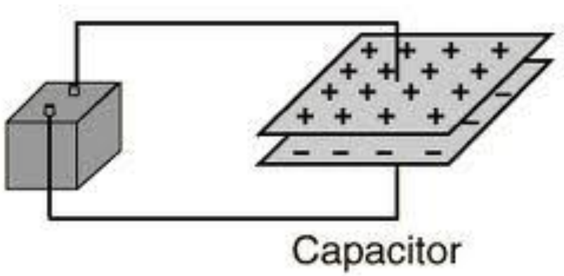
Inductance

- Inductor is a passive electronic component that stores energy in the form of a magnetic field.
- In its simplest form, an inductor consists of a wire loop or coil.
- Inductance is directly proportional to the number of turns in the coil.
- Inductance also depends on the radius of the coil and on the type of material around which the coil is wound.

Passive Element

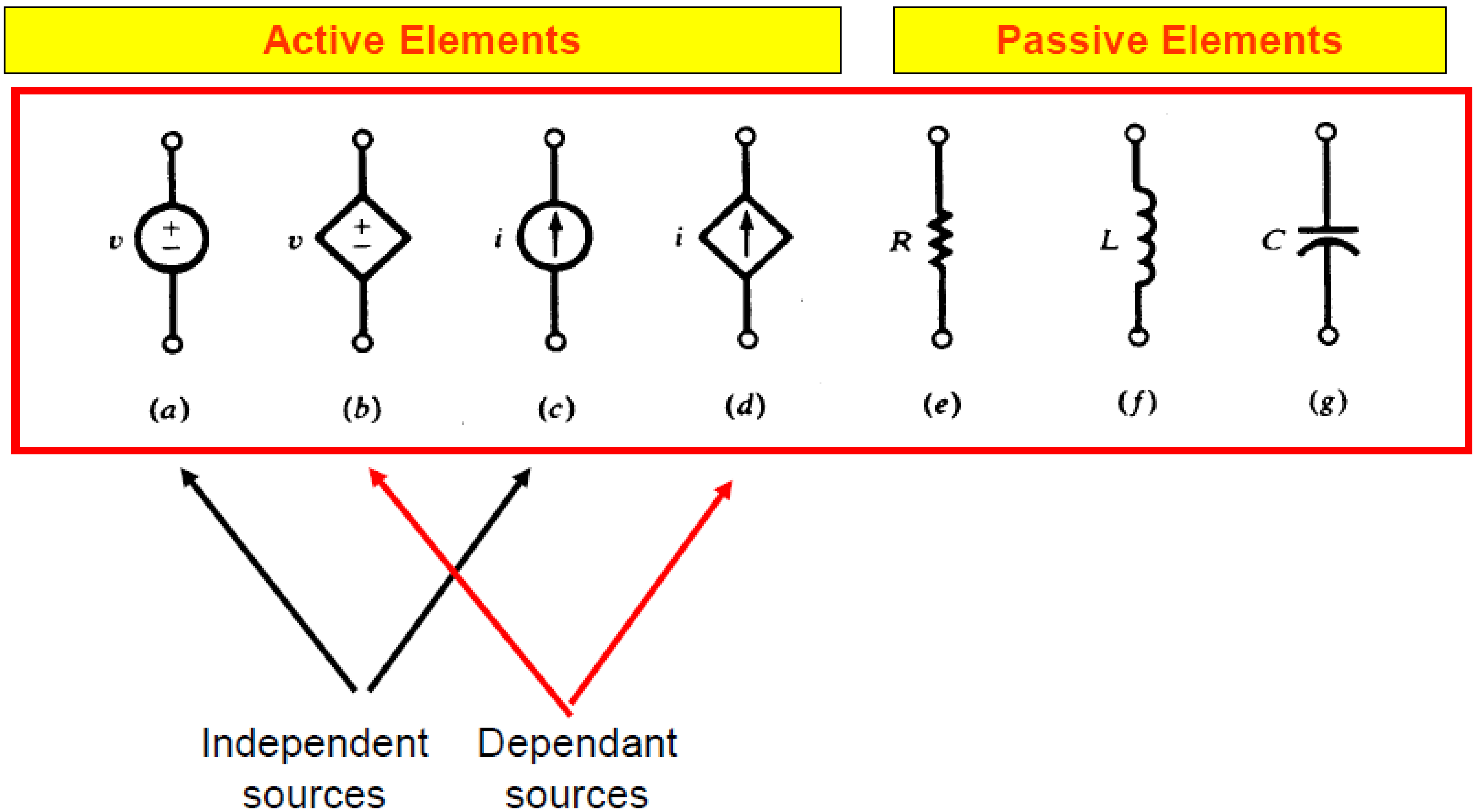
- When a voltage is applied across a **capacitor**, a positive charge is deposited on one plate and a negative charge on the other and the capacitor is said to store a charge
- The charge stored is directly proportional to the applied voltage

$$q = C \cdot V$$

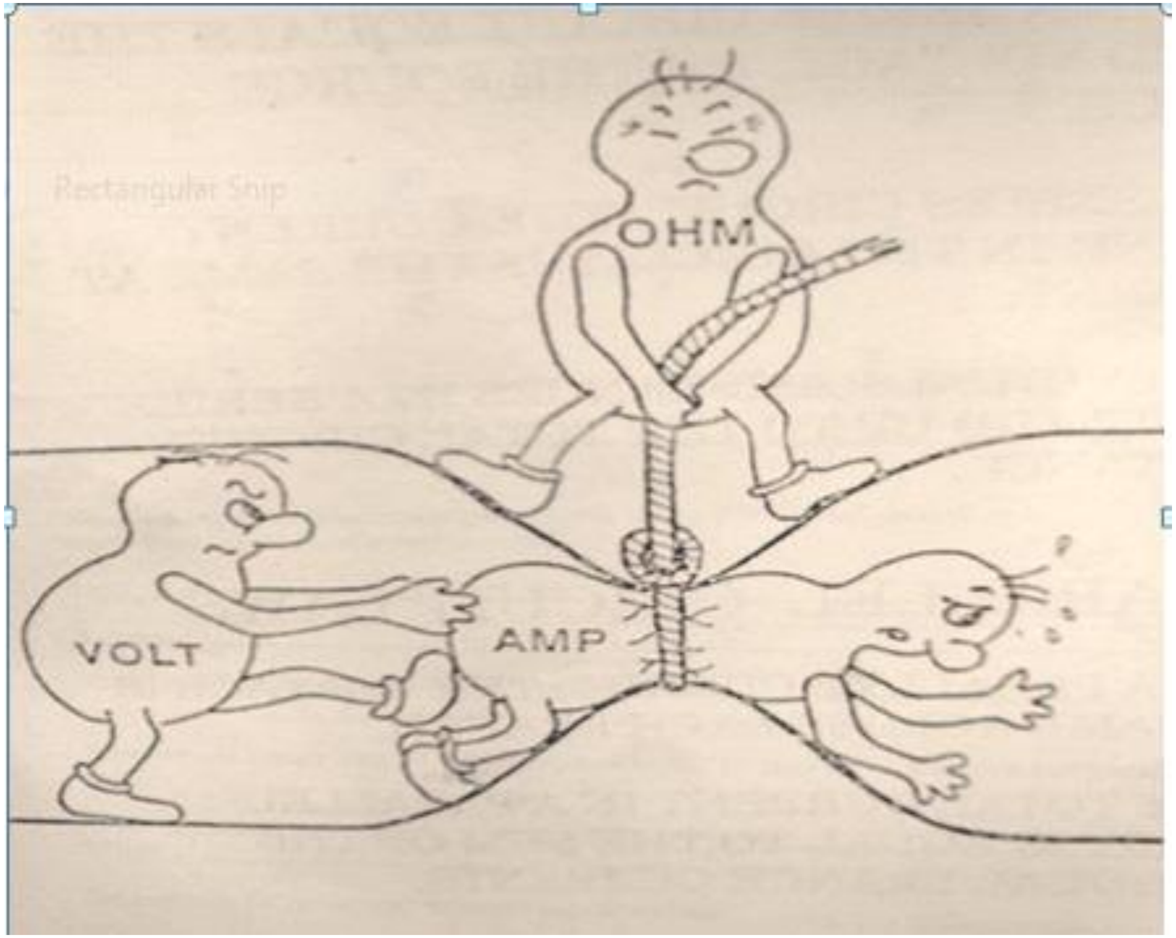


A battery will transport charge from one plate to the other until the voltage produced by the charge buildup is equal to the battery voltage.

Circuit Elements



Pictorial Representation of Ohms Law



Conductance

Conductance is the reciprocal of resistance

Symbol: G

Units: Siemens (S) or mho (℧)

Example:

Consider a 10 W resistor. What is its conductance?

Power Calculation for a Resistor

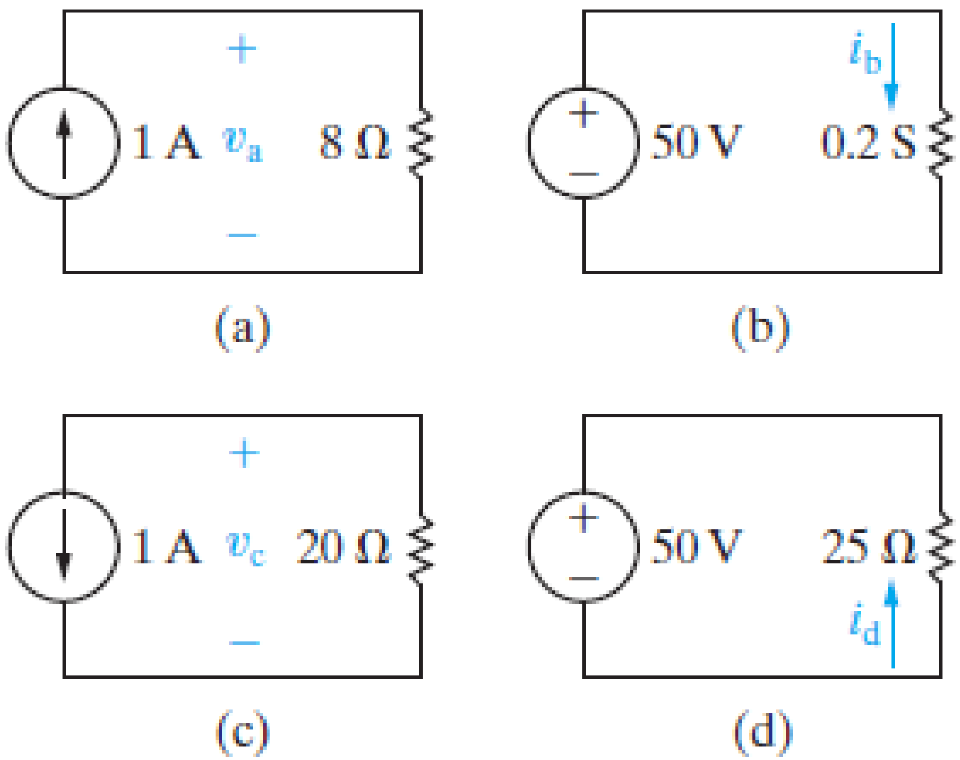
- To calculate power across the resistor

$$P = V * i = (iR) * i = i^2 R$$

- Other method of expressing the power at the terminals of a resistor is in terms of the voltage and resistance.

$$P = \frac{V^2}{R}$$

Calculating Voltage, Current, and Power for a Simple Resistive Circuit



- Calculate the values of *v and i.*
- Determine the power dissipated in each resistor

Kirchoff

Gustav Robert Kirchhoff
(1824-1887)

- In 1845, German physicist Gustav Robert Kirchoff first described two laws that became central to electrical engineering. The laws were generalized from the work of Georg Ohm. The laws can also be derived from Maxwell's equations

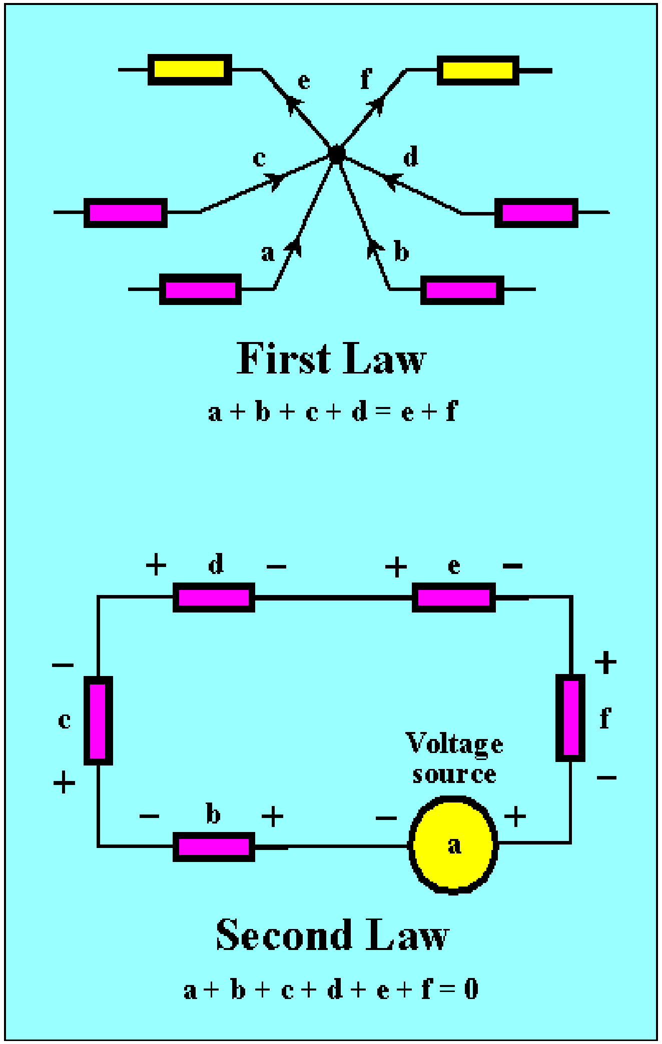
Kirchoff's laws

- Kirchoff's First Law(Current Law)

In any network of wires carrying currents, the algebraic sum of all he currents at a Point is zero.

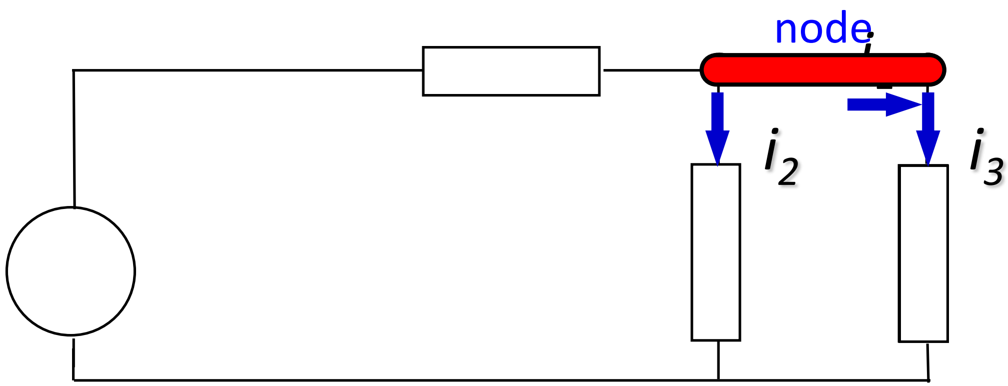
- Kirchoff's Second Law(Voltage Law)

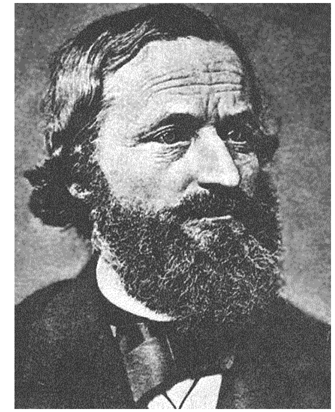
In any closed circuit or mesh, the algebraic sum of EMF's plus voltage drops the algebraic sum of product of current and resistance in the circuit is zero



Kirchhoff’s Current Law

- The sum of currents flowing **into** a node must be balanced by the sum of currents flowing **out** of the node.





Gustav Kirchoff
was an 18th century German mathematician

i_1 flows **into** the node

i_2 flows **out** of the node

i_3 flows **out** of the node

$$\boxed{i_1 = i_2 + i_3}$$

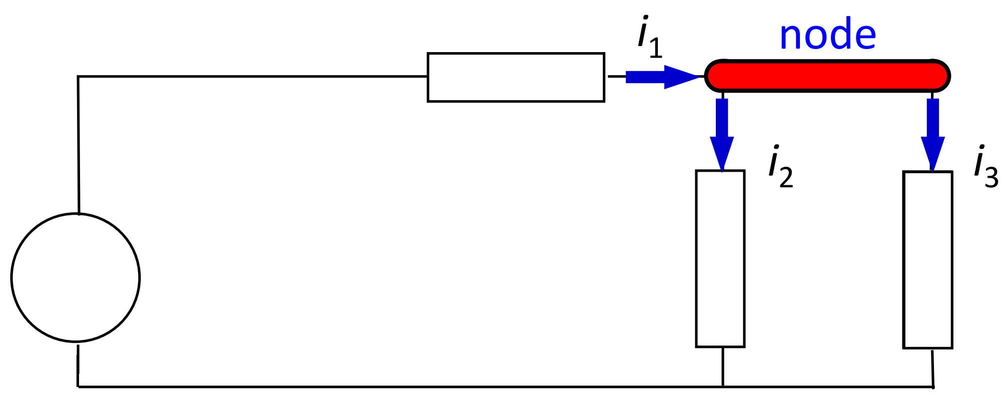
$$\sum i = 0$$

Kirchhoff's Current Law:

$i_1 = i_2 + i_3$

- This equation can also be written in the following form:

$i_1 - i_2 - i_3 = 0$



A formal statement of **Kirchhoff's Current Law**:

The sum of *all* the currents **entering** a node is zero.

(i_2 and i_3 **leave** the node, hence currents $-i_2$ and $-i_3$ **enter** the node.)

Sometimes Kirchhoff's Current Law is abbreviated just by

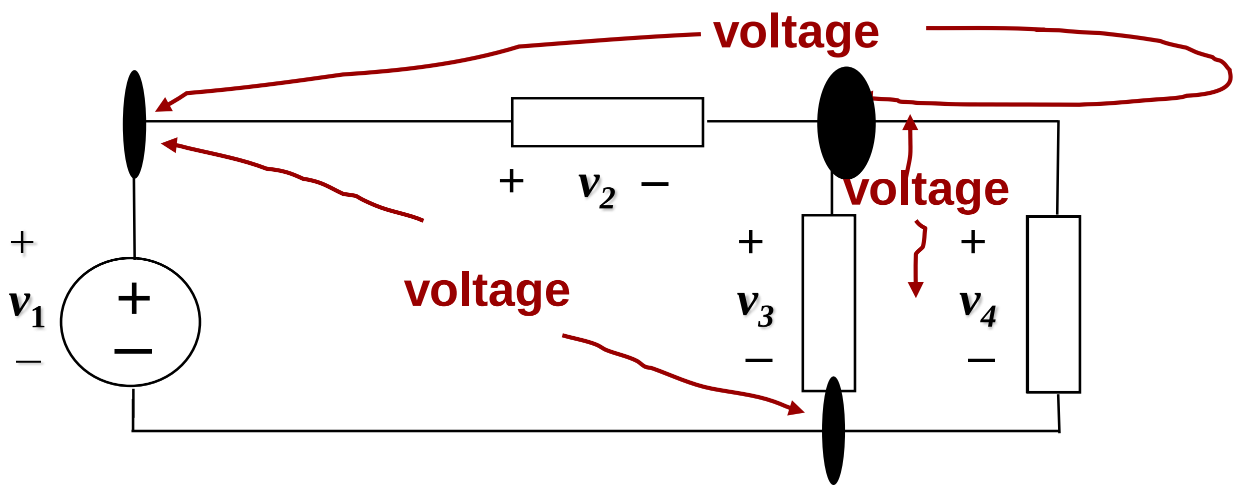
KCL

Review: Different ways to state KCL:

- ✓ The sum of *all* currents **entering** a node must be zero.
- ✓ The net current entering a node must be zero.

Kirchhoff’s Voltage Law

- The voltage measured between any two nodes does not depend of the path taken.



Example of KVL: $v_1 = v_2 + v_3$

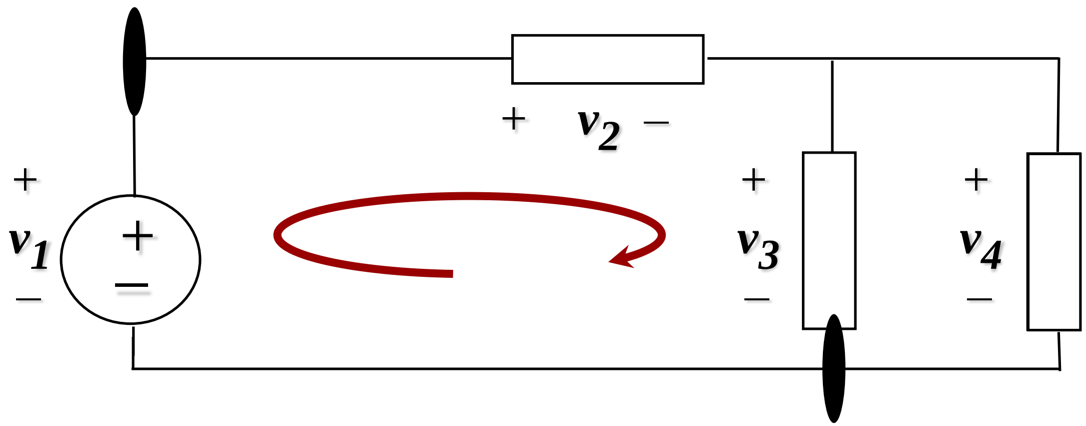
Similarly: $v_1 = v_2 + v_4$

and: $v_3 = v_4$

Kirchhoff's Voltage Law:

$$v_1 = v_2 + v_3$$

$$-v_1 + v_2 + v_3 = 0$$



A formal statement of **Kirchhoff's Voltage Law**:

The sum of voltages around a **closed loop** is zero.

Summary

- Circuit elements are classified active and passive elements
- Active elements are capable of generating electrical energy
- Passive elements are incapable of generating electrical energy
- Basic active elements are voltage and current sources and passive circuit elements are the resistance, inductance and capacitance
- Ohms law states that “Voltage V across a resistor is directly proportional to the current I flowing through the resistor”
- Kirchoff's First Law States that “In any network of wires carrying currents, the algebraic sum of all he currents at a Point is zero”
- Kirchoff's Second Law states that “Algebraic sum of the voltages across any set of branches in a closed loop is zero”