Intro. to Basic Electronics

Instructors:

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General Information

- **Suggested pre-requisites**:
  - Basic course on applied electricity and linear algebra, Knowledge of electrical components will be an advantage.
- **Course Content**:
  - Introduction to Electronics and its Applications
  - Semiconductor Materials and Properties
  - Semiconductor Diodes
  - Semiconductor Diodes and Applications
  - Bipolar Junction Transistor
  - Transistor as an Amplifier
  - Operational Amplifier
  - Switching Theory and Logic Design
- **Grading** :
  - Midterm : 30% Final Exams 70%

Reference Books

- Electronic Principles by Albert Paul Malvino (copies can be found in both Engineering and Main Lib.)
- Electronic Engineering by Sanjay Sharma PhD. (copies can be found at Kingdom Books)
- etc

Semesters' Plan

Wk	Lecture Days
2	Introduction to Electronics and its Applications
2-3	Semiconductor Materials and Properties
4-5	Semiconductor Diodes
6-8	Semiconductor Diodes and Applications
9	***Tutorials and Midterm Exams***
10-11	Bipolar Junction Transistor
12-13	Transistor as an Amplifier
14	Operational Amplifier
15	Switching Theory and Logic Design
16	Revision

Intro. to
Electricity and Electronics

What is Electronics

Electronics is the branch of physics and technology concerned with the design of circuits using transistors and microchips, and with the behaviour and movement of electrons in a semiconductor, conductor, vacuum, or gas

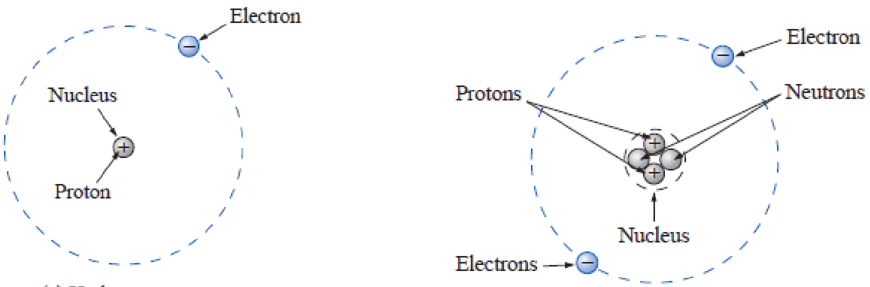
System of Units

Multiplication Factors	SI Prefix	SI Symbol
$1\,000\,000\,000\,000 = 10^{12}$	tera	T
$1\,000\,000\,000 = 10^{9}$	giga	G
$1\,000\,000 = 10^{6}$	mega	M
$1\,000 = 10^{3}$	kilo	k
$0.001 = 10^{-3}$	milli	m
$0.000\,001 = 10^{-6}$	micro	μ
$0.000\,000\,001 = 10^{-9}$	nano	n
$0.000\,000\,000\,001 = 10^{-12}$	pico	p

Applications

Atoms And Their Structure

- Everything is made of atoms
- The simplest of all atoms is the hydrogen atom.
- It is made up of two basic particles
  - the proton
  - the electron



(a) Hydrogen atom
(b) Helium atom

- In all other elements the nucleus also contains **neutrons** which have no charge
- In every element the number of protons is equivalent to the number of electrons.

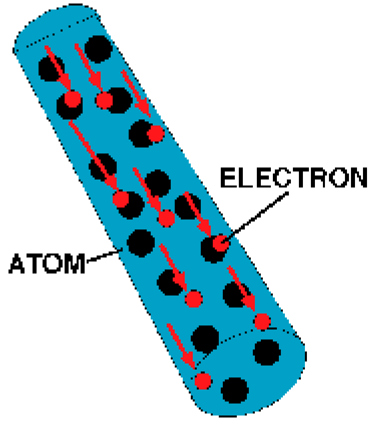
Coulomb's Law

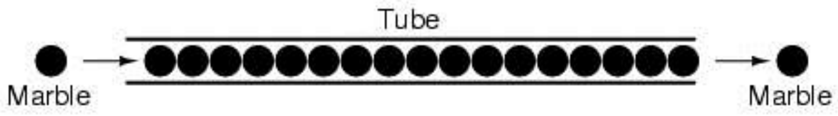
$$F \text{ (attraction or repulsion)} = \frac{kQ_1Q_2}{r^2}$$

- Unlike charges attract; like charges repel.
- So there are forces of attraction acting in the atom between the **protons** in the nucleus and the **electrons** in the orbiting shells.
- This force is stronger when they are closer and weaker when they are far apart.
- Therefore it is easier to break away an electron that is distant from the nucleus.
- Also it is easier to break an electron from a shell that is incomplete and has fewer electrons. ($2n^2$)

Electricity

- An electron that breaks away from its atom is known as a **Free Electron.**
- These free electrons are known as **charge carriers.**
- The movement of free electrons is known as **current of Electricty**.

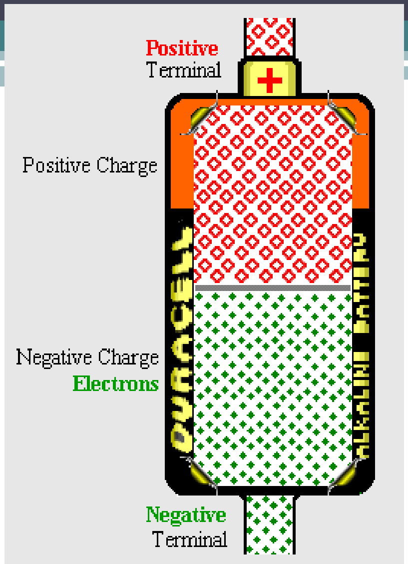




- Some materials have strong attraction and refuse to lose electrons (have less free electrons), these are called **insulators** (air, porcelain, oils, Bakelite, rubber, teflon, glass, mica)

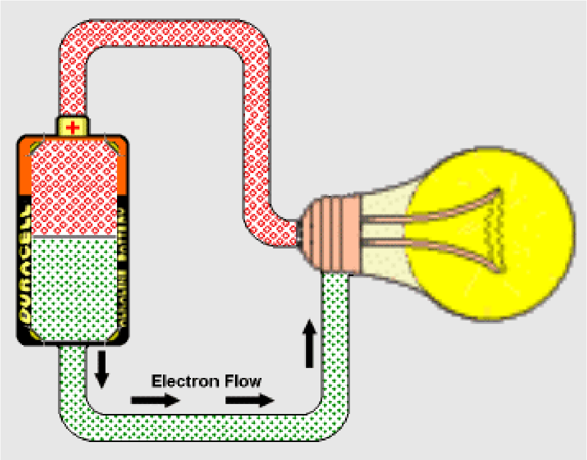
- Some materials have weak attractions and allow electrons to be lost, these are called **conductors** (silver, copper, gold, aluminium, tungsten, nickel, iron)

- Surplus of electrons is called a negative charge (-). A shortage of electrons is called a positive charge (+).



- A battery provides a surplus of electrons by chemical reaction.

- By connecting a conductor from the positive terminal to negative terminal electrons will flow.



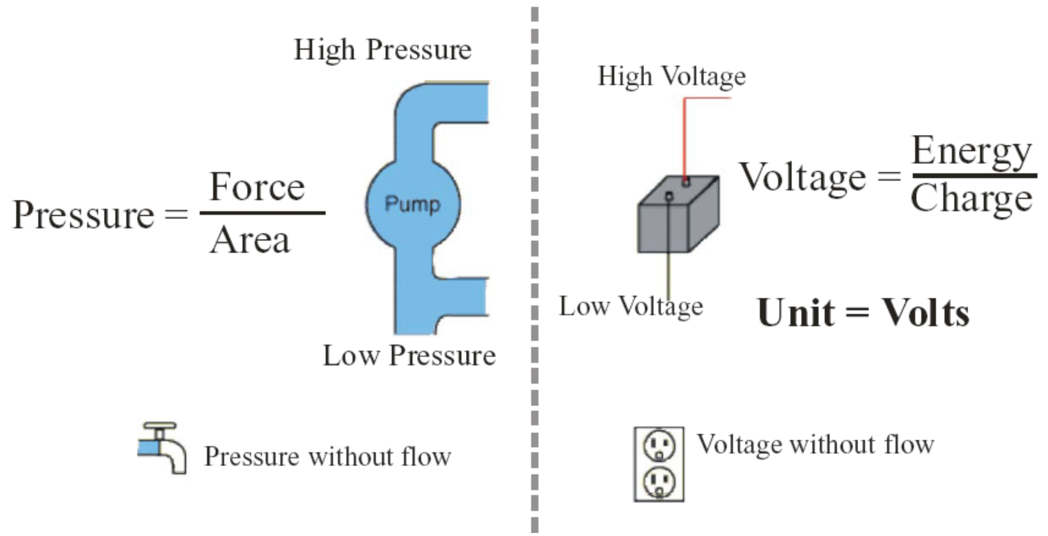
Potential Difference(Voltage)

- The applied potential difference (measured in volts) of a voltage source in an electric circuit is the “pressure” needed to set the system in motion and “cause” the flow of charge or current through the electrical system.
- Compare this pressure to the pressure from a water tap connected to a hose

V E Potential

Voltage = **E**lectro-**M**otive **F**orce, the driving force in electron flow

Water Analogy | Electrical Equivalent



Voltage Sources:

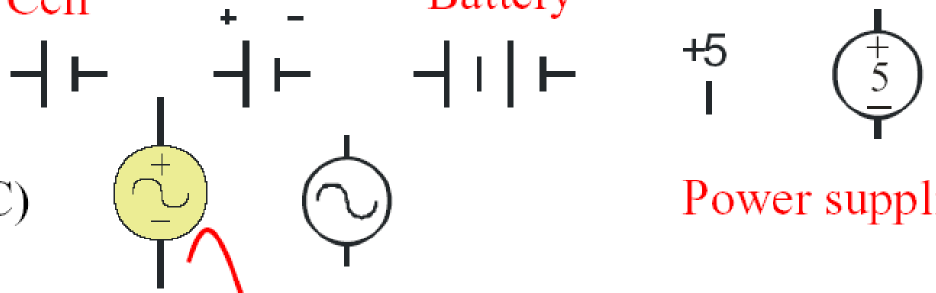
Symbols

Cell

Battery

UniPolar

BiPolar (AC)



Power supplies

Properties

Constant Voltage, independent of the amount of current

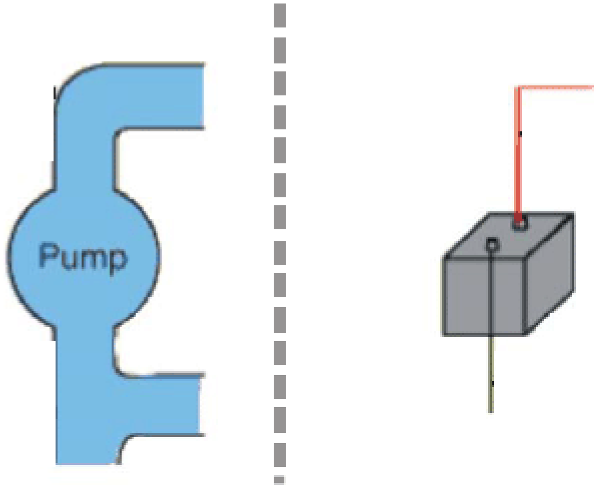
Usually ideal

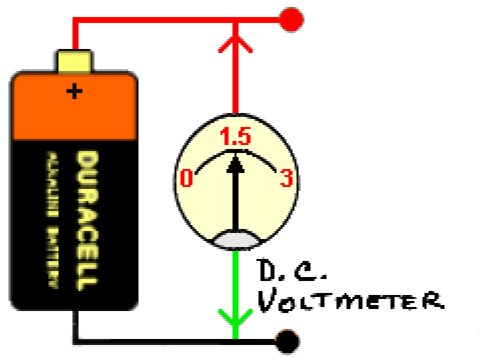
Examples

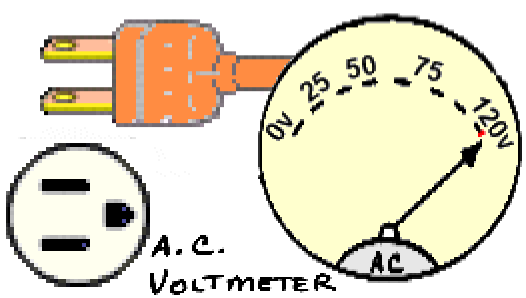
Batteries

Power Supplies

Signal Generators







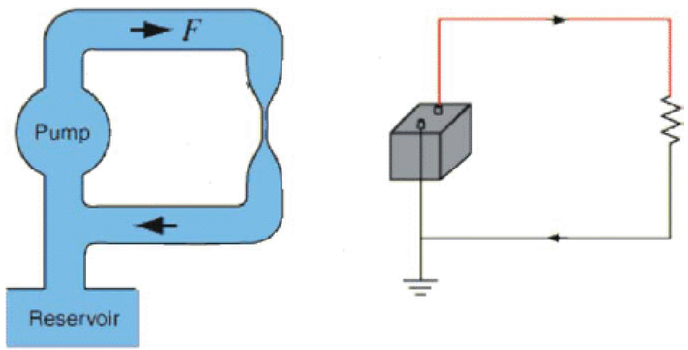
- Voltage is like differential pressure, always measure between two points.

- Measure voltage between two points or across a component in a circuit.

- When measuring DC voltage make sure polarity of meter is correct, positive (+) red, negative (-) black.

Ground

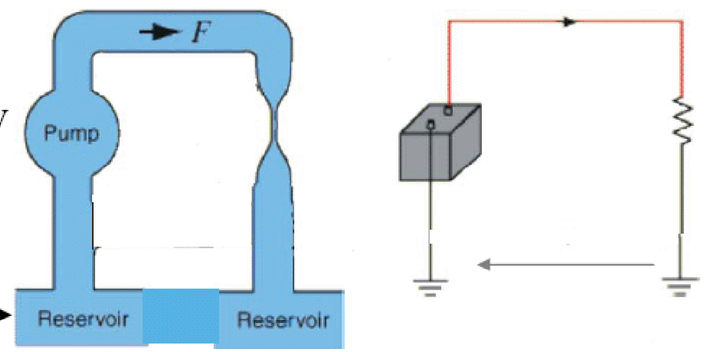
Provides a reference point



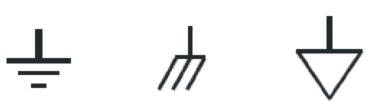
Purely a reference point

Does not participate in current flow

An integral path in the current flow



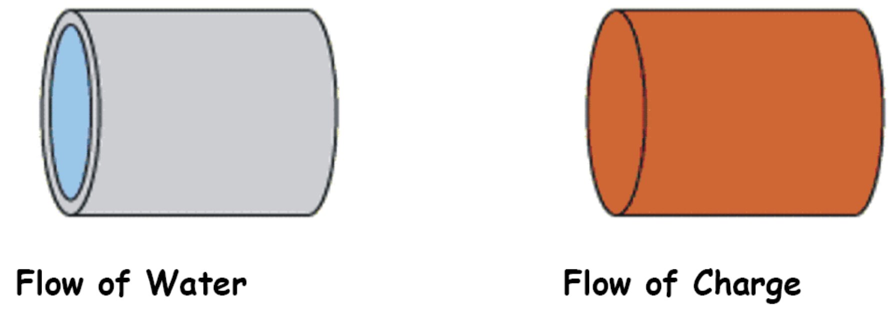
Symbols



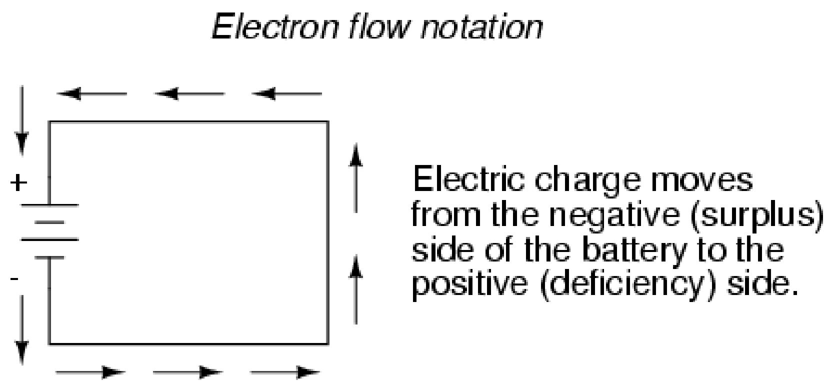
Earth

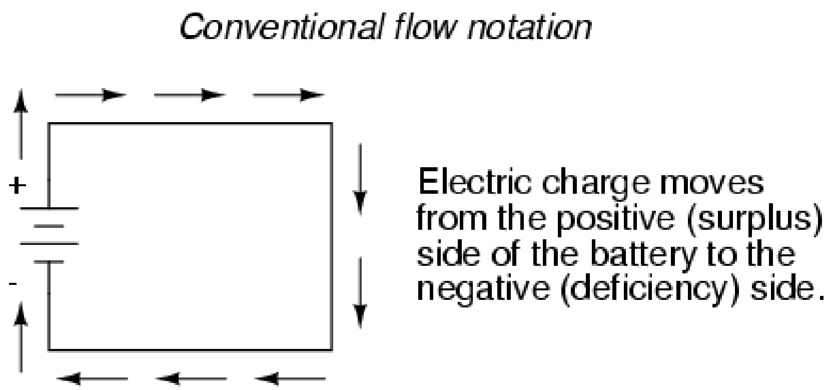
Analog Gnd

Current

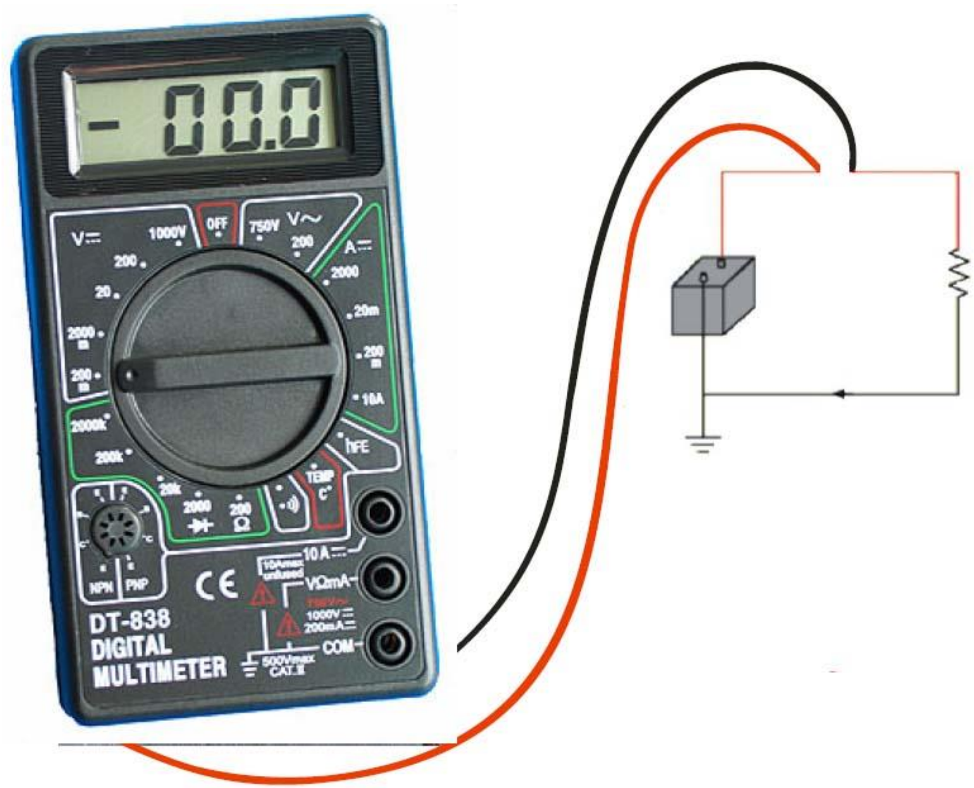


- Uniform flow of electrons thru a circuit is called *current*.



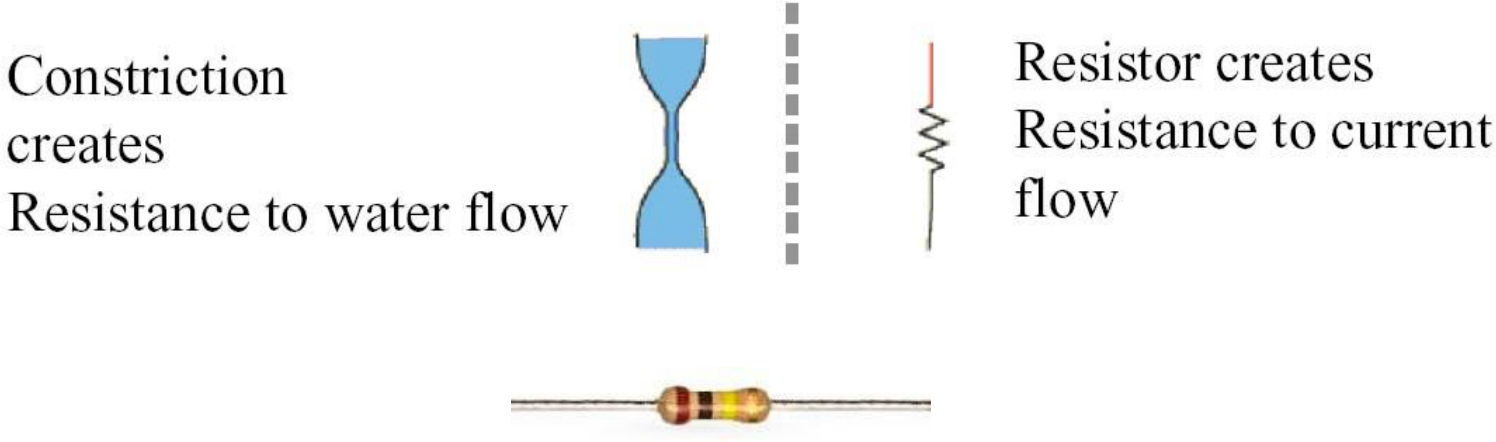


WILL USE CONVENTIONAL FLOW NOTATION ON ALL SCHEMATICS



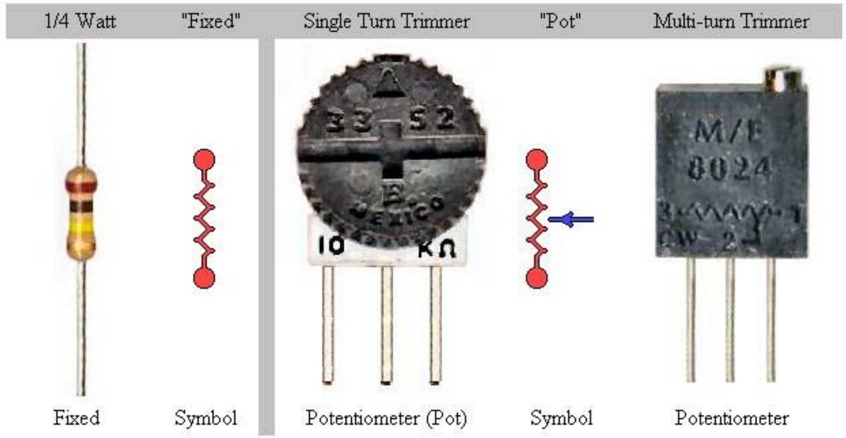
- To measure current, must break circuit and install meter in line.
- Measurement is imperfect because of voltage drop created by meter.

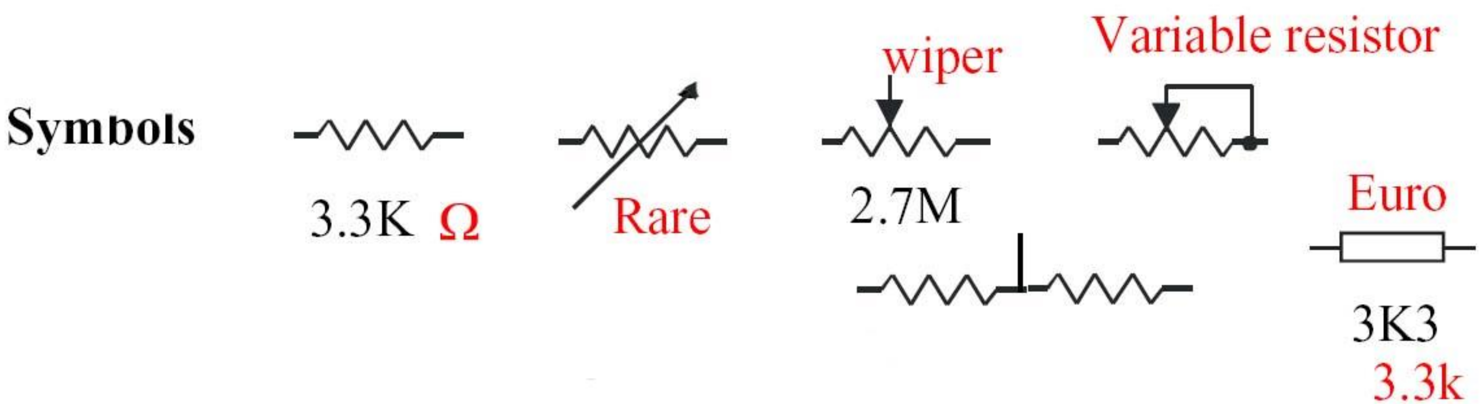
Resistance

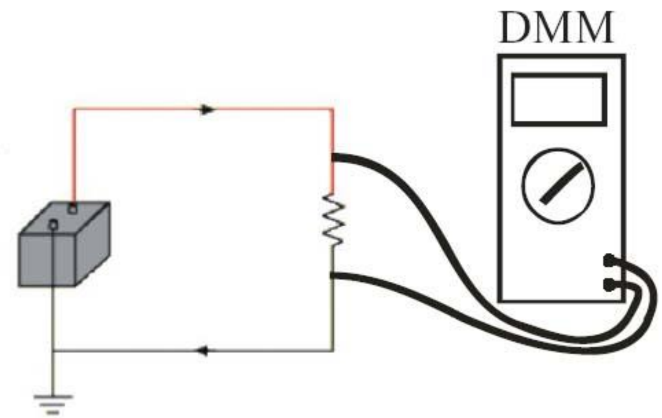


- The resistance of a material is the opposing force that a flowing charge encounters
- All materials have a resistance that is dependent on cross-sectional area, material type and temperature.
- A resistor dissipates power in the form of heat

Various resistors types



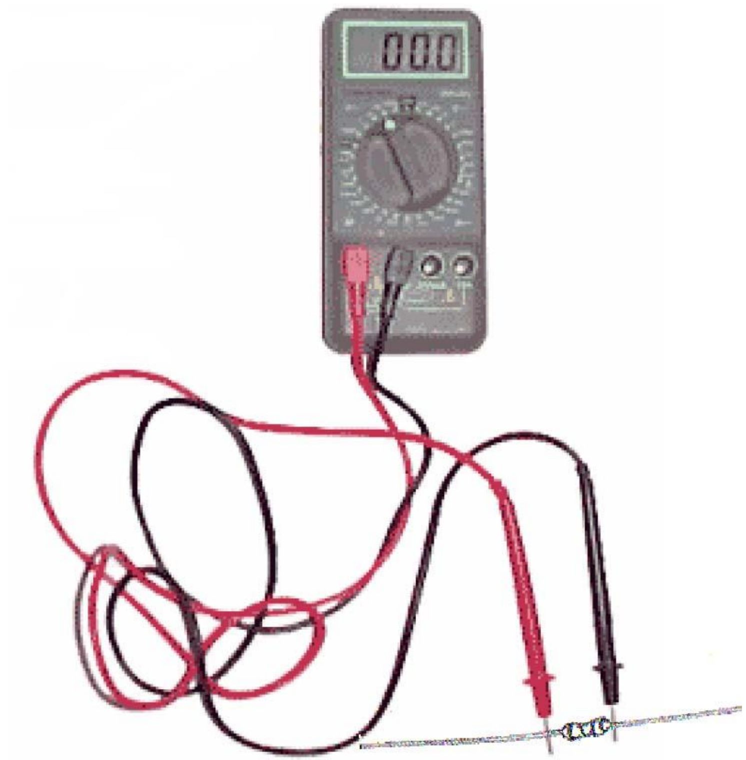




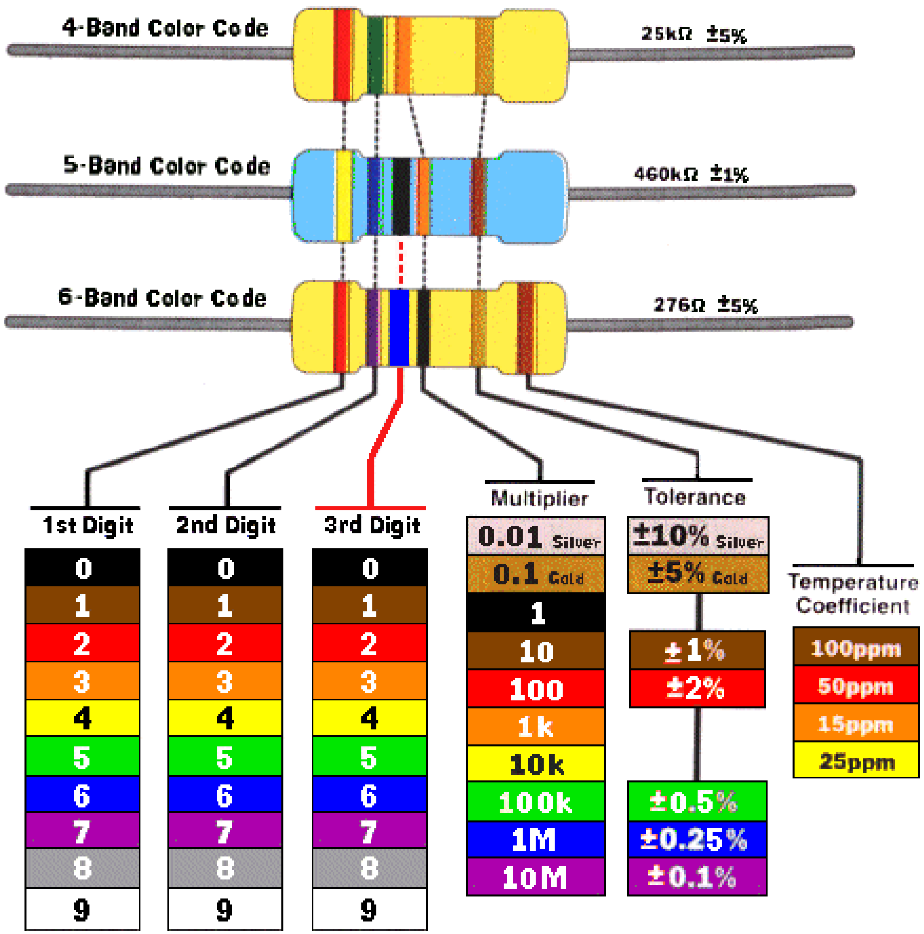
Will this work like we expect it to?

NO! don't do this!

When measuring resistance, remove component from the circuit.

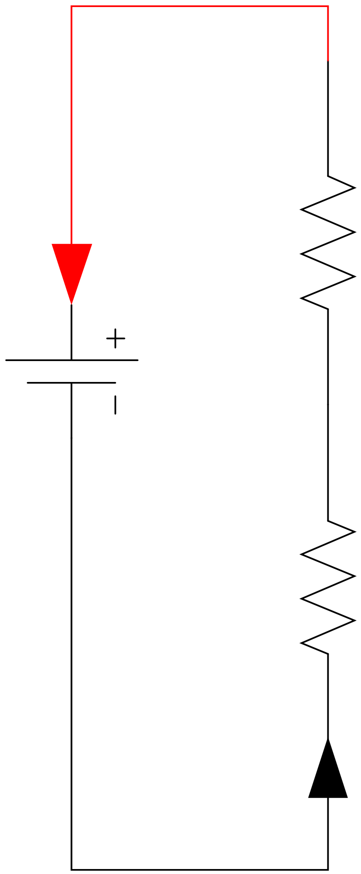


Resistor Color Code



Resistors in Circuits Series

- Looking at the current path, if there is only one path, the components are in series.

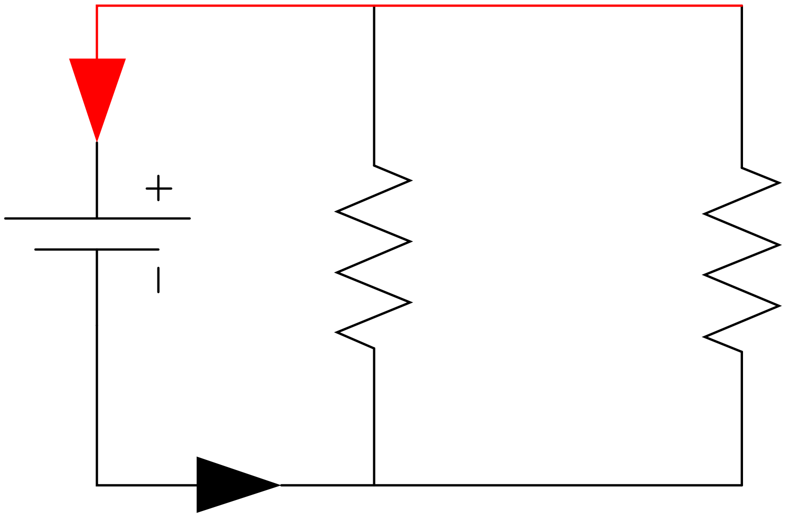


Resistors in Circuits
Series

$$R_1 + R_2 + R_n$$

Resistors in Circuits Parallel

- If there is more than one way for the current to complete its path, the circuit is parallel



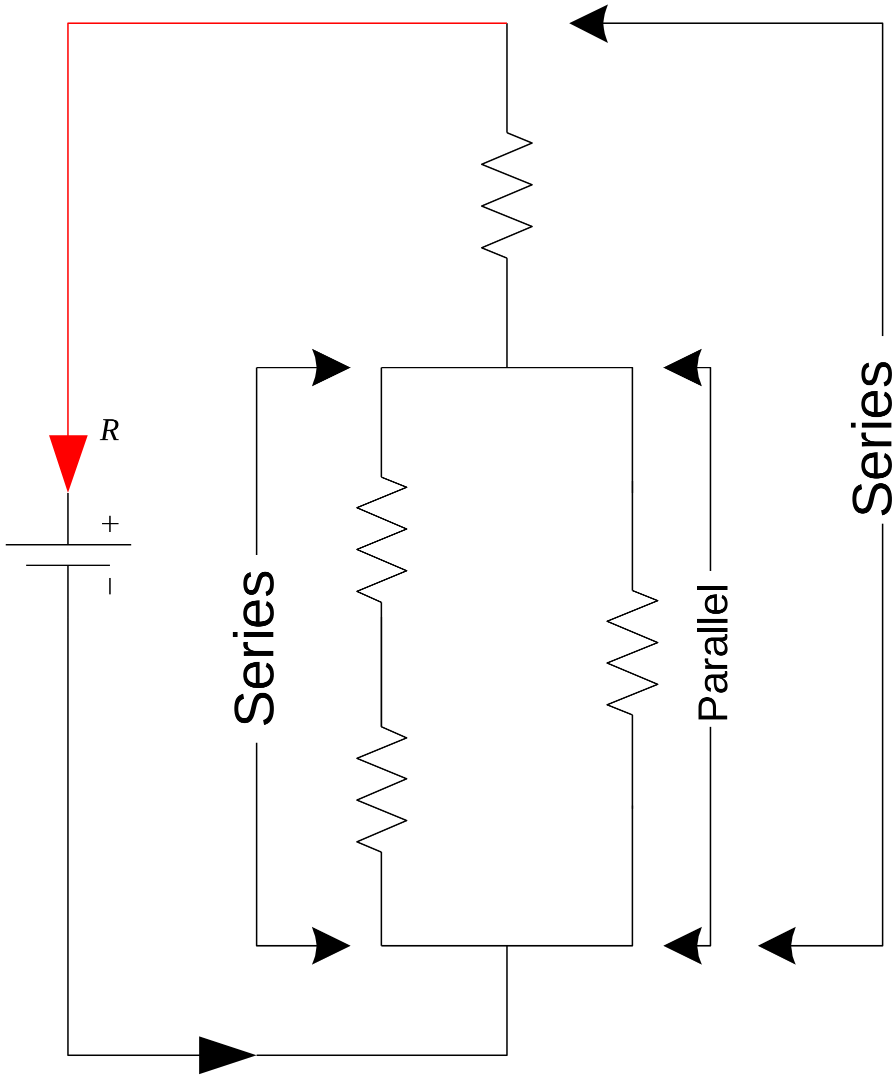
Resistors in Circuits
Parallel

$$\frac{1}{\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_n}}$$

$$\frac{R_1 R_2}{R_1+R_2}$$

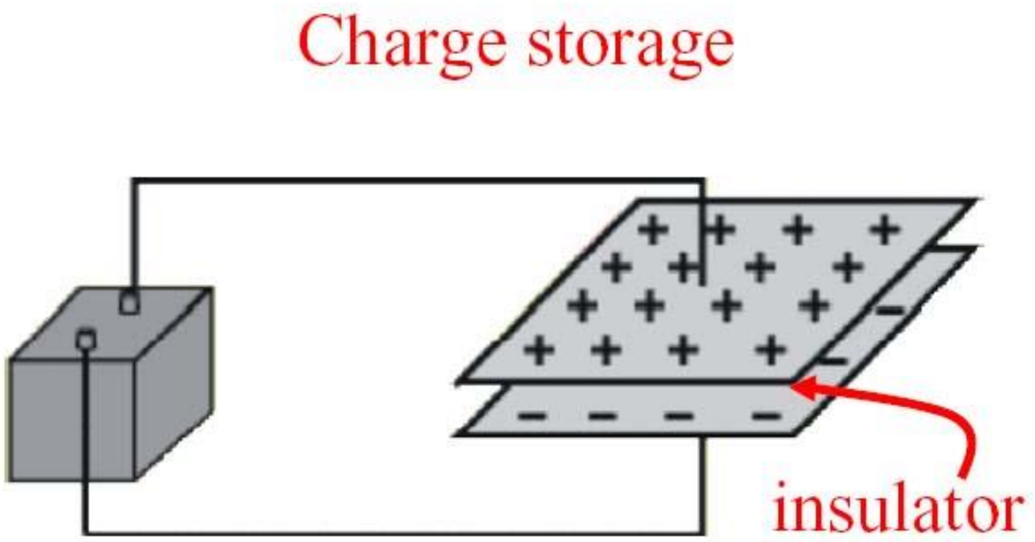
Resistors in Circuits Mixed

- If the path for the current in a portion of the circuit is a single path, and in another portion of the circuit has multiple routes, the circuit is a mix of series and parallel.



Capacitance

A capacitor is used to store charge for a short amount of time



Capacitor

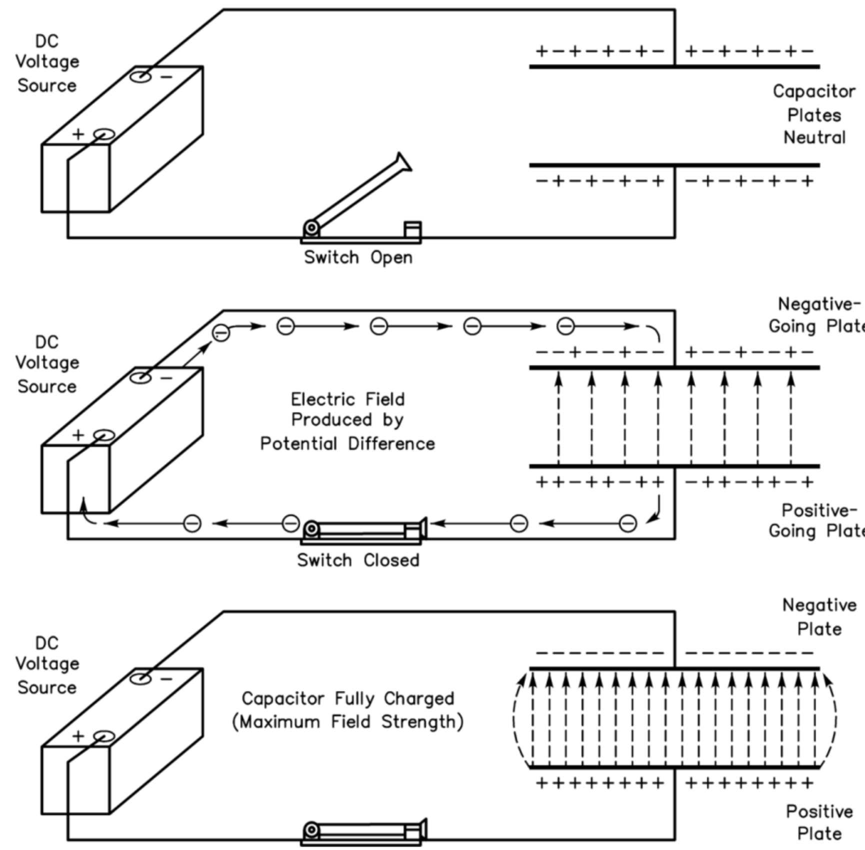
Battery

Unit = Farad

Pico Farad - pF = 10^{-12}F
Micro Farad - uF = 10^{-6}F

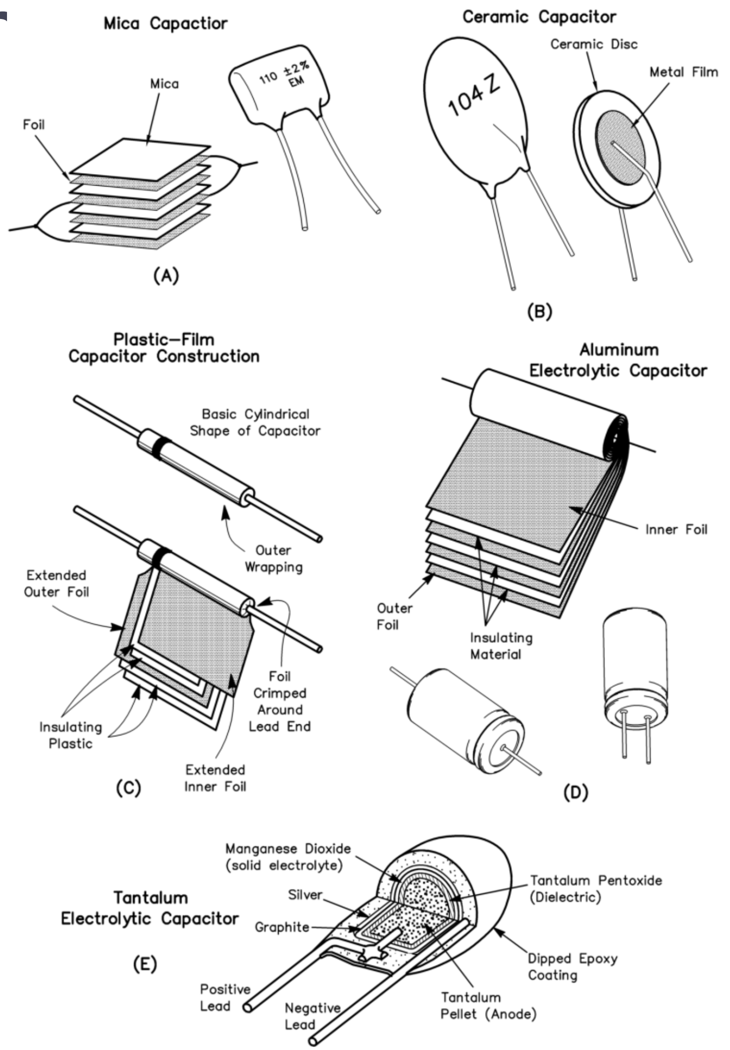
The Capacitor Defined

- A device that stores energy in electric field.
- Two conductive plates separated by a non conductive material.
- Electrons accumulate on one plate forcing electrons away from the other plate leaving a net positive charge.
- Think of a capacitor as very small, temporary storage battery.



The Capacitor Physical Constructior

- Capacitors are rated by:
  - Amount of charge that can be held.
  - The voltage handling capabilities.
  - Insulating material between plates.



Symbols nonPolar

Polar Euro

Properties

Characteristic Equations: $I = C\frac{dV}{dT}$

$$V = \frac{1}{C}\int IdT$$ Integrating Charge (storage)

Markings

Polar vs Non-Polar

Values

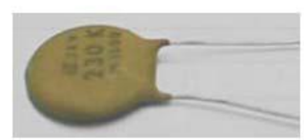
Electrolytics mark (-)
Tantalums mark (+)
Longer lead

Examples

Mylar

Monolythic Cermamic

Tantalum

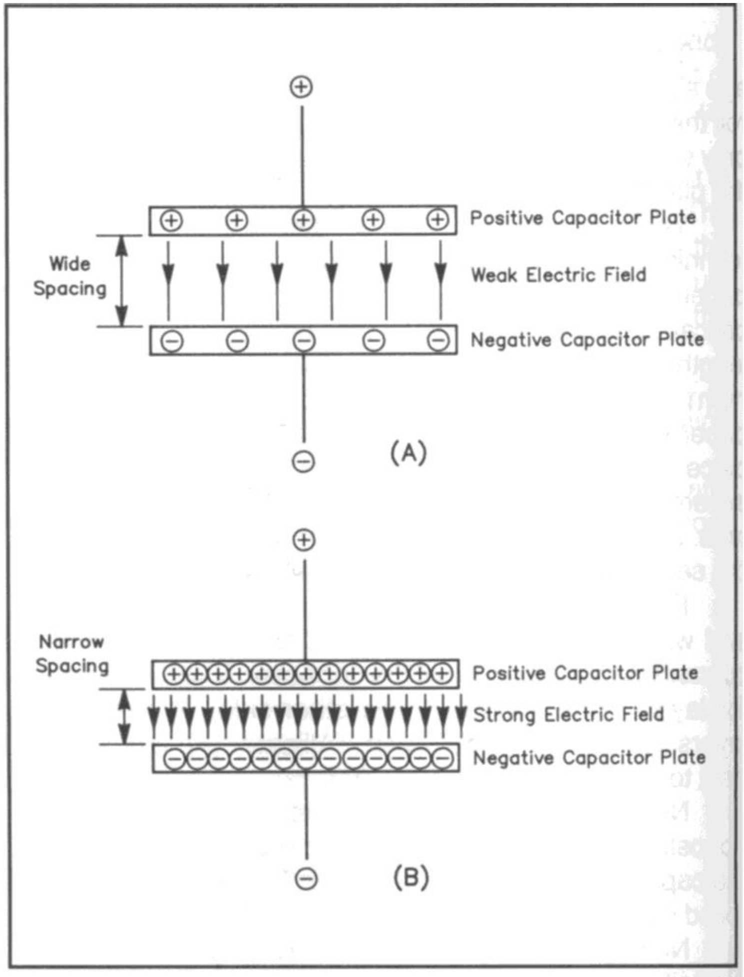


Ceramic

Electrolytic

The Capacitor
Ability to Hold a Charge

- Ability to hold a charge depends on:
  - Conductive plate surface area.
  - Space between plates.
  - Material between plates.



The Capacitor Behavior in DC

- When exposed to DC, the capacitor charges and holds the charge as long as the DC voltage is applied.
- The capacitor essentially blocks DC voltage from passing through.

The Capacitor Behavior in AC

- When AC current is applied, during one half of the cycle the capacitor accepts a charge in one direction.
- During the next half of the cycle, the capacitor is discharges then recharged in the reverse direction.
- During the next half cycle the pattern reverses.
- Essentially, it appears that AC current passes through a capacitor

The Capacitor Behavior

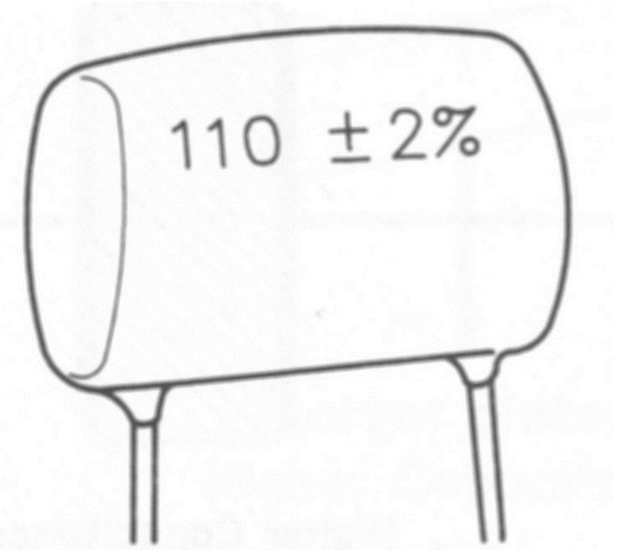
- A capacitor blocks the passage of DC
- A capacitor passes AC

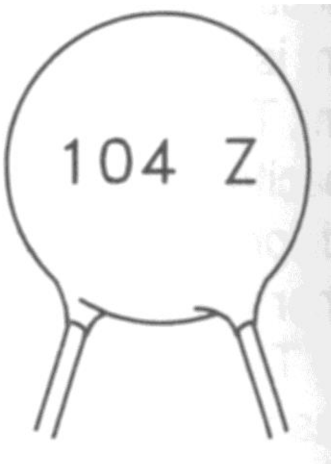
The Capacitor
Capacitance Value

- The unit of capacitance is the farad.
  - A single farad is a huge amount of capacitance.
  - Most electronic devices use capacitors that have a very tiny fraction of a farad.
- Common capacitance ranges are:
  - Micro μ - 10^{-6}
  - Nano n - 10^{-9}
  - Pico p - 10^{-12}

The Capacitor Capacitance Value

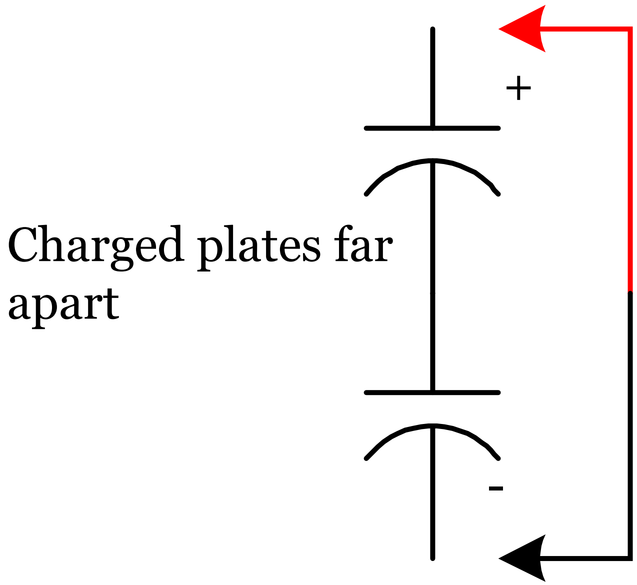
- Capacitor identification depends on the capacitor type.
- Could be color bands, dots, or numbers.
- Wise to keep capacitors organized and identified to prevent a lot of work trying to re-identify the values.





Capacitors in Circuits

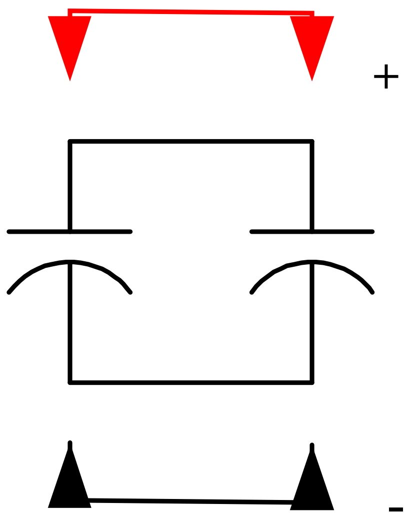
- Two physical factors affect capacitance values.
  - Plate spacing
  - Plate surface area
- In series, plates are far apart making capacitance less



$$\frac{C_1 C_2}{C_1 + C_2}$$

Capacitors in Circuits

- In parallel, the surface area of the plates add up to be greater, and close together.
- This makes the capacitance more the Capacitor



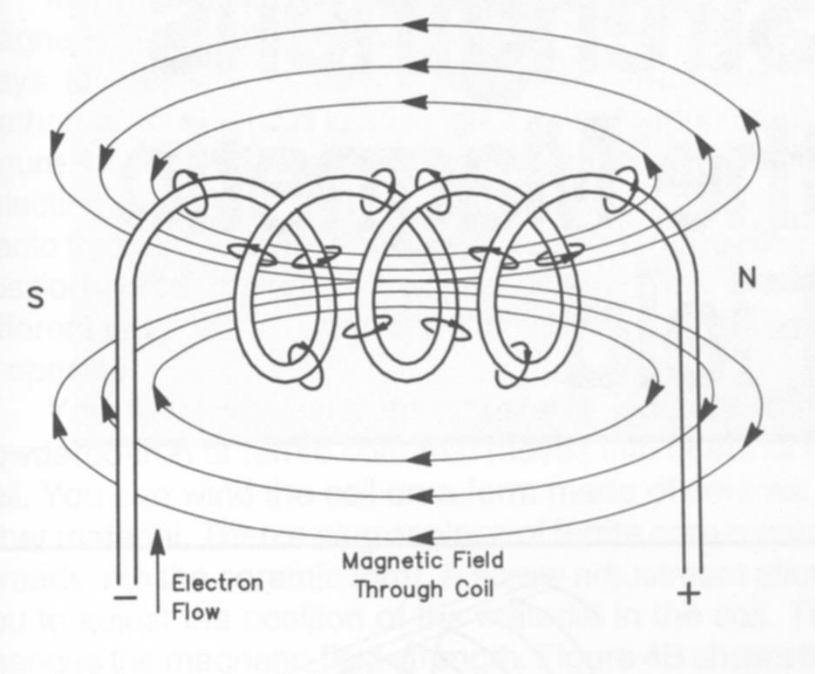
$$C_1 + C_2$$

The Inductor

- There are two fundamental principles of electronics:
  1. Moving electrons create a magnetic field.
  2. Moving or changing magnetic fields cause electrons to move.
- An inductor is a coil of wire through which electrons move, and energy is stored in the resulting magnetic field.

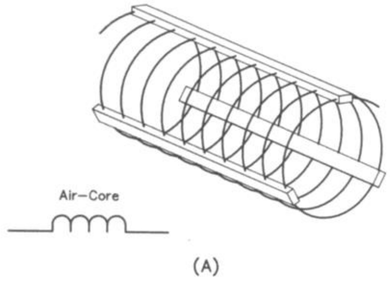
The Inductor

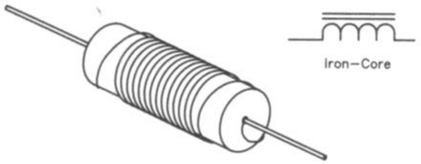
- Like capacitors, inductors temporarily store energy.
- Unlike capacitors:
  - Inductors store energy in a magnetic field, not an electric field.
  - When the source of electrons is removed, the magnetic field collapses immediately.

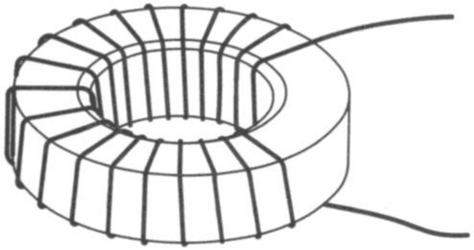


The Inductor

- Inductors are simply coils of wire.
  - Can be air wound (nothing in the middle of the coil)
  - Can be wound around a permeable material (material that concentrates magnetic fields)
  - Can be wound around a circular form (toroid)





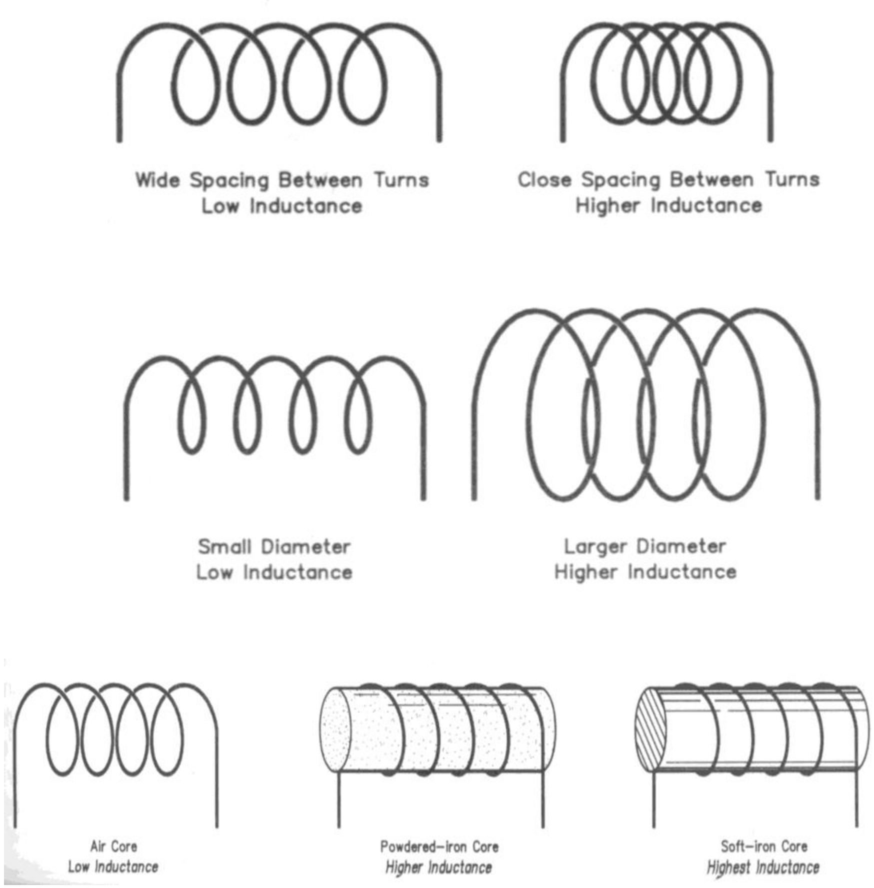


The Inductor

- Inductance is measured in Henry(s).
- A Henry is a measure of the intensity of the magnetic field that is produced.
- Typical inductor values used in electronics are in the range of milli Henry (1/1000) and micro Henry (1/1,000,000)

The Inductor

- The amount of inductance is influenced by a number of factors:
  - Number of coil turns.
  - Diameter of coil.
  - Spacing between turns.
  - Size of the wire used.
  - Type of material inside the coil.



Inductor Performance With DC Currents

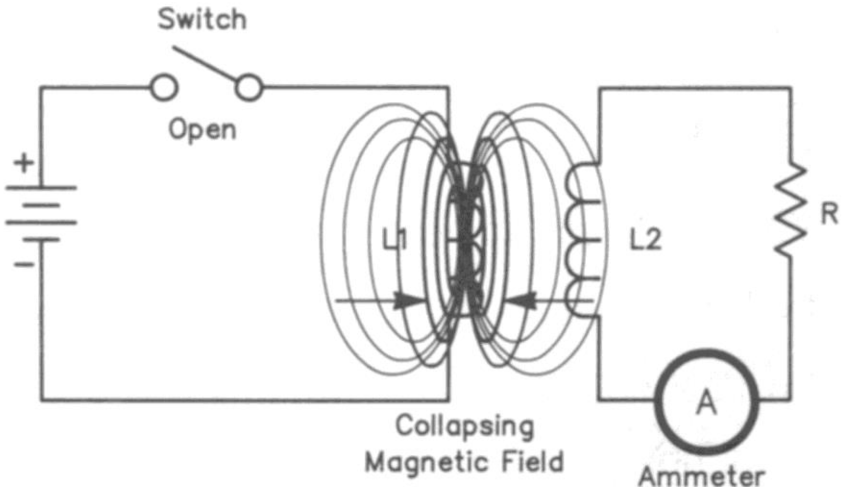
- When DC current is applied to an inductor, the wire in the inductor momentarily appears as a short circuit and maximum current flows.
- As the magnetic field builds (changes) there is a tendency for the current flow to slow down (due to an opposition cause the the changing magnetic field).
- Finally, the magnetic field is at its maximum and the current flows to maintain the field.
- As soon as the current source is removed, the magnetic field begins to collapse and creates a rush of current in the other direction, sometimes at very high voltages.

Inductor Performance With AC Currents

- When AC current is applied to an inductor, during the first half of the cycle, the magnetic field builds as if it were a DC voltage.
- During the next half of the cycle, the current is reversed and the magnetic field first has to decrease the reverse polarity in step with the changing current.
- Depending on the value of inductance, these forces can work against each other, making for a less than simple situation.

The Inductor

- Because the magnetic field surrounding an inductor can cut across another inductor in close proximity, the changing magnetic field in one can cause current to flow in the other … the basis of transformers



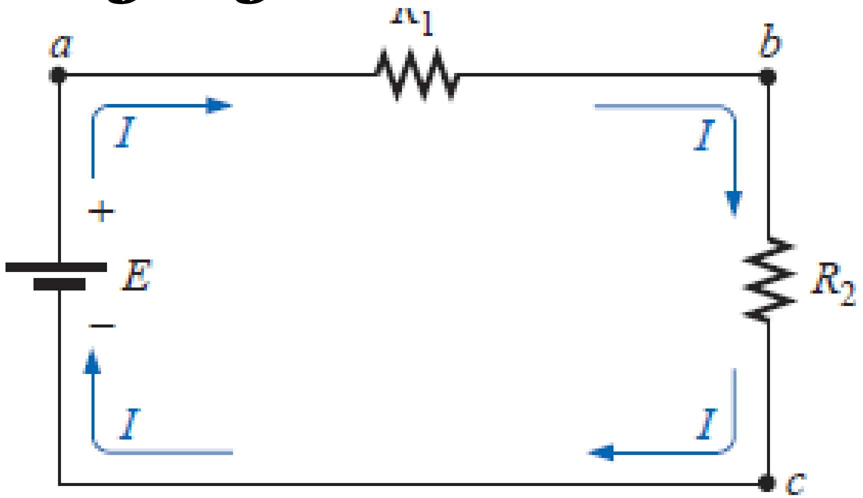
Laws and Principles of Electricity and Electronics

Laws and Rules

- Ohm’s
- Kirchhoff’s
- Voltage Divider
- Current Divider
- Thevenin’s
- Norton’s

Reminder: Elements in series

- Two elements are in series if
- ***1. They have only one terminal in common (i.e., one lead of one is connected to only one lead of the other).***
- ***2. The common point between the two elements is not connected to another current-carrying element.***



Reminder: Resistors in series

- The total resistance of a series circuit is the sum of the resistance levels.

$$\boxed{R_T = R_1 + R_2 + R_3 + \cdots + R_N}$$

Ohm’s Law

- The mathematical relationship
  - E=I*R
- Doing the math

Ohm's Law

- In 1827 George Ohm proved there was a direct relationship between Voltage (E), Current (I), and Resistance (R) in an electrical circuit. This relationship is known as Ohm's Law.
- Ohm's Law states that current in a circuit is proportional to the voltage and inversely proportional to the resistance.

Ohm’s Law

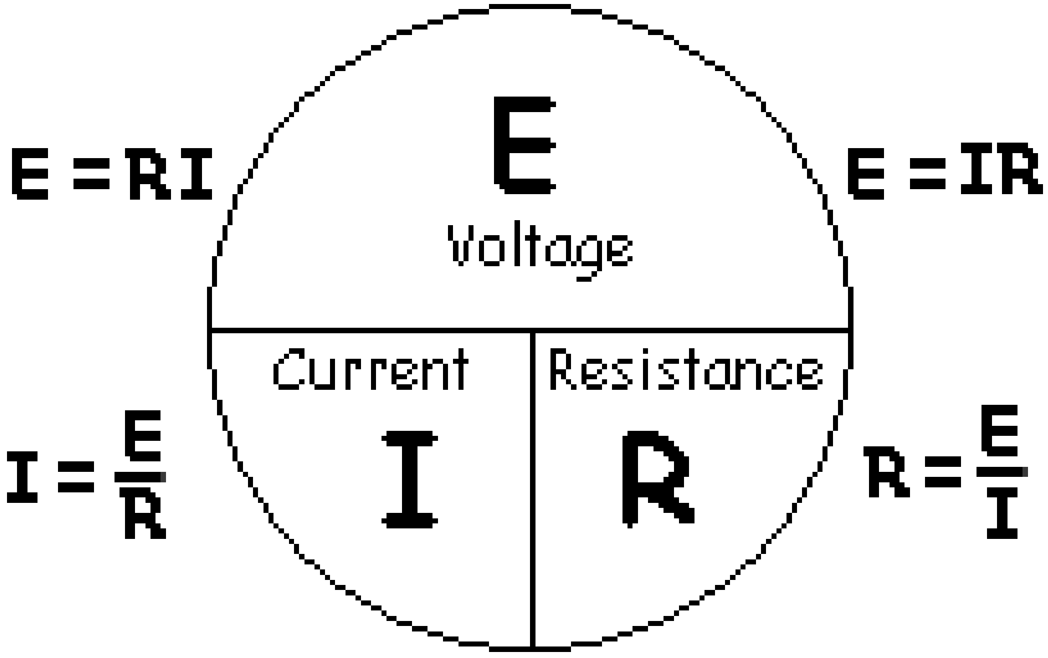
- There is a mathematical relationship between the three components of electricity. That relationship is **Ohm’s Law.**
  - **E** = volts
  - **R** = resistance in ohms
  - **I** = current in amps

$$E = I * R$$

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

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

Ohm's Law



E = Voltage - Volts
I = Current - Amps
R = Resistance or Reactance
(Impedence) - Ohms

Question

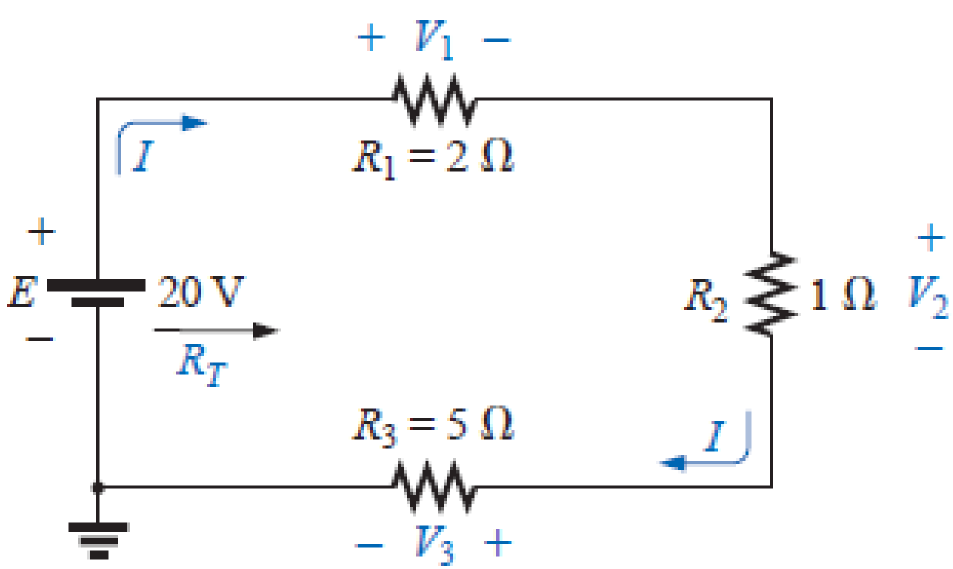
a. Find the total resistance for the series circuit of Fig. 5.7.

b. Calculate the source current *Is*.

c. Determine the voltages *V*1, *V*2, and *V*3.

d. Calculate the power dissipated by *R*1, *R*2, and *R*3.

e. Determine the power delivered by the source, and compare it to the sum of the power levels of part (d).



Power

- Transforming energy from one form to another is called ***work***. The greater the energy transformed, the more work that is done.
- There are six basic forms of energy and they are light, heat, magnetic, chemical, electrical, and mechanical energy.
- The unit for measuring ***work*** is called the ***Joule (J).***

Power

- ***Power (P)*** is the rate at which ***work*** is performed and is measured by the unit called ***Watt (W). Watts = Joules per second.***
- The output ***Power, or power ratings*** of electrical, electronic or mechanical devices can be expressed in ***Watts (W)*** and describes the number of ***Joules*** of energy converted every second.

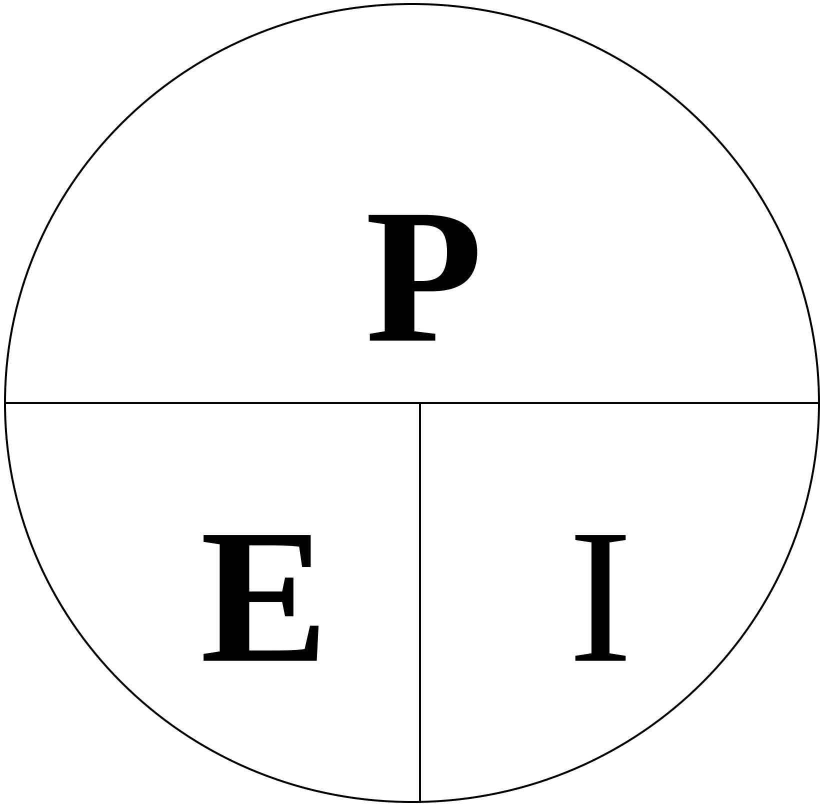
Power

- ***Power*** is the rate at which electric energy (***W***) is converted to some other form and can be expressed mathematically as $\boldsymbol{P = I \times V}$.
- This formula states that the amount of power delivered to a device is dependent on the electrical pressure (or voltage applied across the device) and the current flowing through the device.

Power Formula

- The ***Power Formula*** is the relationship between Power (P), Voltage (E), and Current (I).

P = Power -Watts
E = Voltage - Volts
I = Current - Amps



Power Formula

- The ***Power Formula*** states that if the voltage in a circuit changes, the current in the circuit also changes. The power required from a circuit changes any time loads are added (power increases) or removed (power decreases).
- The ***Power Formula*** is used when troubleshooting and to predict circuit characteristics before power is applied.

Combining Ohm's Law and Power Formula

- ***Ohm's Law*** and the ***Power Formula*** may be combined mathematically and written as any combination of Voltage (E), Current (I), Resistance (R), or Power (P).
- ***Ohm's Law*** and the ***Power Formula*** are limited to circuits in which electrical resistance is the only significant opposition to the flow of current. This limitation includes all DC circuits and AC circuits that do no contain a significant amount of inductance and/or capacitance – which we will learn about later.

Combining Ohm's Law and Power Formula

P = Watts

$$\text{Watts} = \frac{\text{Volts}^2}{\text{Ohms}}$$

$$\text{Watts} = \text{Amperes}^2 \times \text{Ohms}$$

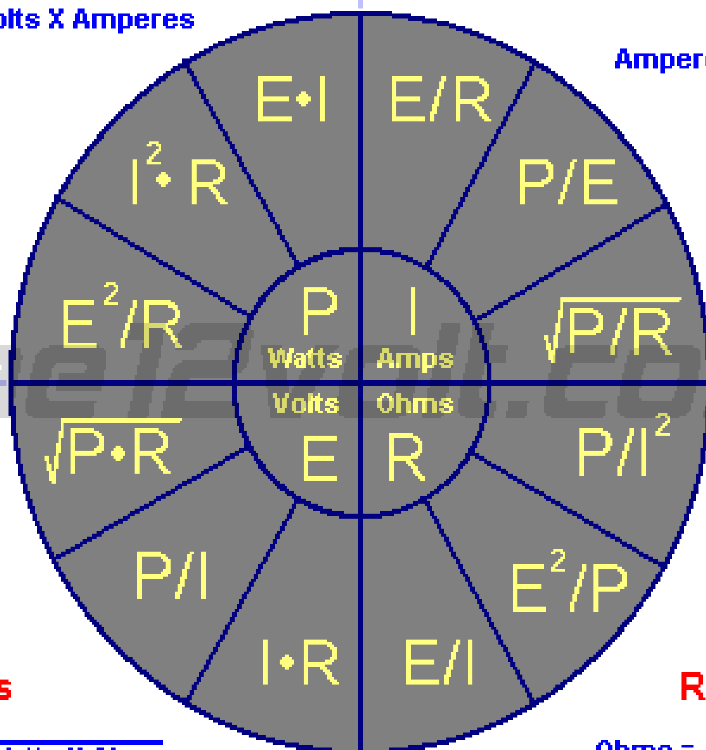
$$\text{Watts} = \text{Volts} \times \text{Amperes}$$

I = Amperes

$$\text{Amperes} = \frac{\text{Volts}}{\text{Ohms}}$$

$$\text{Amperes} = \frac{\text{Watts}}{\text{Volts}}$$

$$\text{Amperes} = \sqrt{\frac{\text{Watts}}{\text{Ohms}}}$$



E = Volts

$$\text{Volts} = \sqrt{\text{Watts} \times \text{Ohms}}$$

$$\text{Volts} = \frac{\text{Watts}}{\text{Amperes}}$$

$$\text{Volts} = \text{Amperes} \times \text{Ohms}$$

R = Ohms

$$\text{Ohms} = \frac{\text{Volts}}{\text{Amperes}}$$

$$\text{Ohms} = \frac{\text{Volts}^2}{\text{Watts}}$$

$$\text{Ohms} = \frac{\text{Watts}}{\text{Amperes}^2}$$

Kirchhoff's Voltage Law (KVL)

- The algebraic sum of the voltage that rises and drops around a closed loop is equal to zero
- $E_T - V_1 - V_2 - V_3 - \cdots - V_n = 0$

$$\boxed{\Sigma_{\circlearrowright} V_{\text{rises}} = \Sigma_{\circlearrowright} V_{\text{drops}}}$$

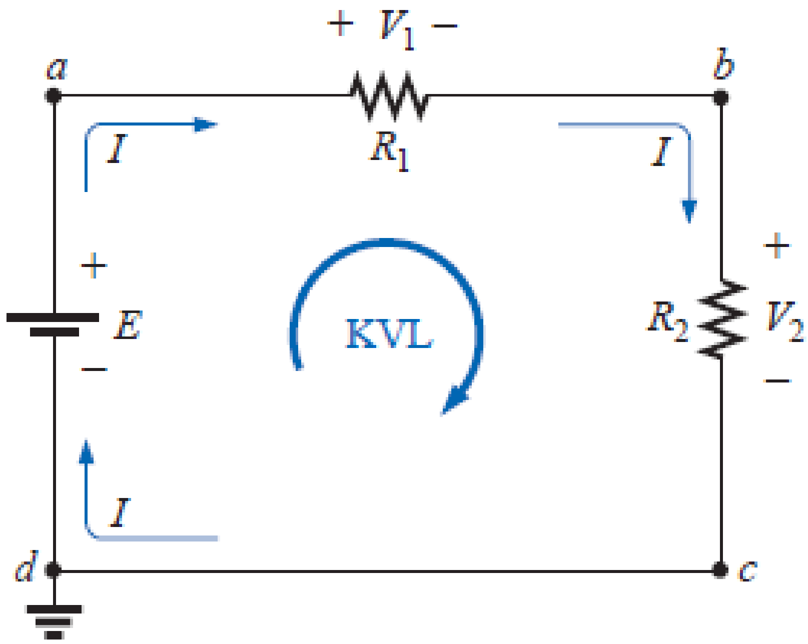
Kirchhoff's Voltage Law (KVL)

- Another way of stating KVL is:
  - Summation of voltage rises is equal to the summation of voltage drops around a closed loop

$$V_1 + V_2 + V_3 + \cdots + V_n = E_T$$

Kirchhoff's Voltage Law (KVL)

- ***the applied voltage of a series circuit equals the sum of the voltage drops across the series elements.***



$$\Sigma_{\circlearrowright} V = 0$$

$$-E + V_2 + V_1 = 0$$

$$E = V_1 + V_2$$

Kirchhoff's Voltage Law (KVL)

a. Find *RT*.

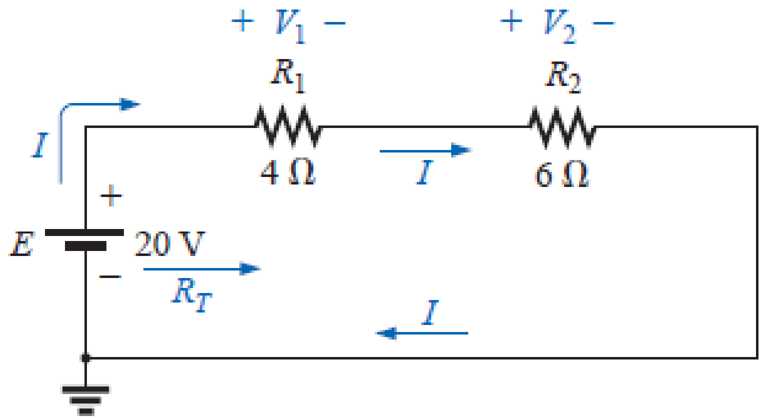
b. Find *I*.

c. Find *V*1 and *V*2.

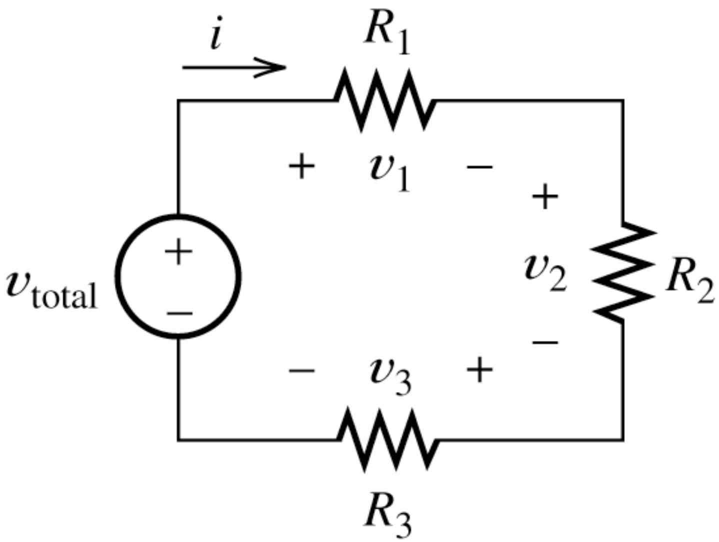
d. Find the power to the 4- and 6- resistors.

e. Find the power delivered by the battery, and compare it to that dissipated
by the 4- and 6- resistors combined.

f. Verify Kirchhoff's voltage law (clockwise direction).



Voltage Divider Rule



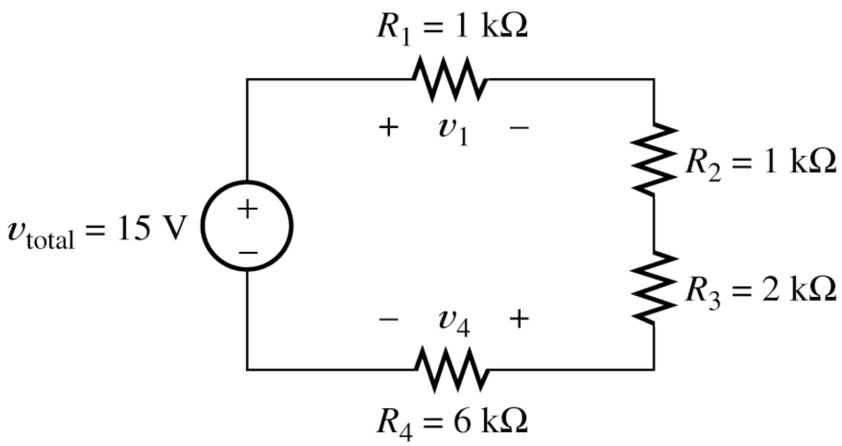
$$v_1 = R_1 i = \frac{R_1}{R_1 + R_2 + R_3} v_{\text{total}}$$

$$v_2 = R_2 i = \frac{R_2}{R_1 + R_2 + R_3} v_{\text{total}}$$

$$\boxed{v_k = \frac{R_k}{R_1 + R_2 + \cdots + R_N} v}$$

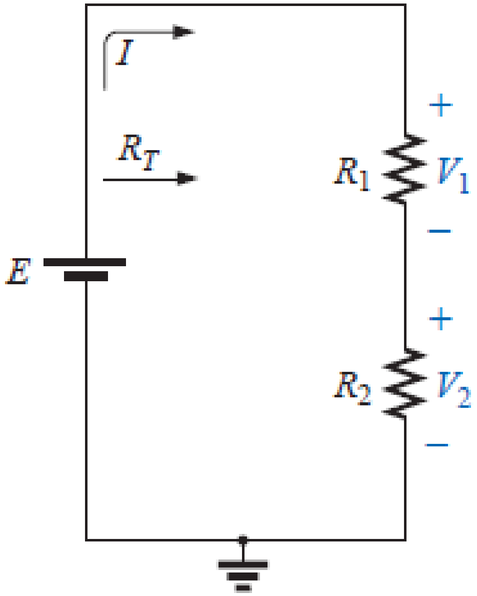
The voltage across the resistive elements will divide as the magnitude of the resistance levels.

Application of the Voltage-Division Principle



$$
\begin{aligned}
v_1 &= \frac{R_1}{R_1 + R_2 + R_3 + R_4} v_{\text{total}} \\
&= \frac{1000}{1000 + 1000 + 2000 + 6000} \times 15 \\
&= 1.5\text{V}
\end{aligned}
$$

Simplifying the Voltage Divider Rule



$$R_T = R_1 + R_2$$

and $$I = \frac{E}{R_T}$$

Applying Ohm's law:

$$V_1 = IR_1 = \left(\frac{E}{R_T}\right)R_1 = \frac{R_1E}{R_T}$$

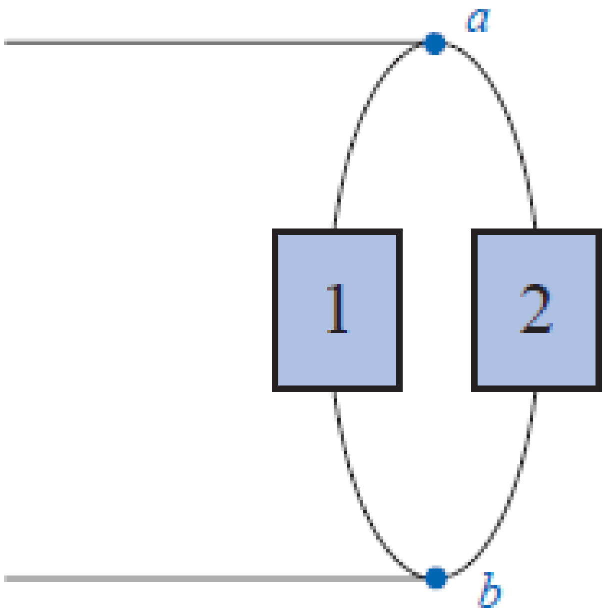
with $$V_2 = IR_2 = \left(\frac{E}{R_T}\right)R_2 = \frac{R_2E}{R_T}$$

Note that the format for V_1 and V_2 is

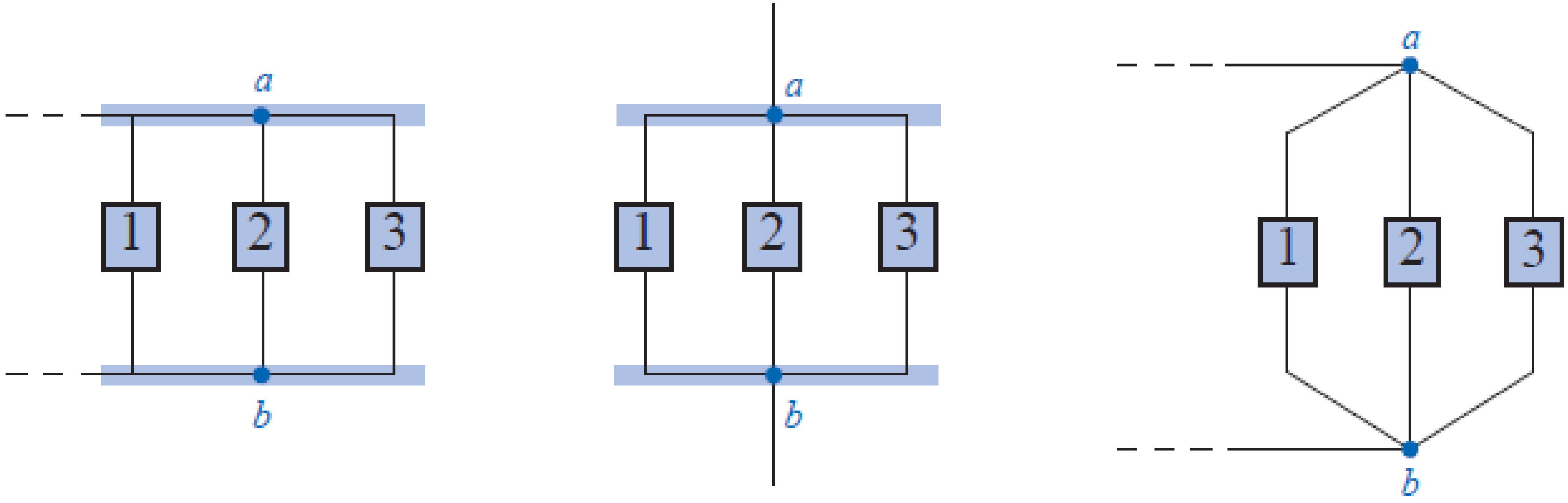
$$\boxed{V_x = \frac{R_xE}{R_T}} \qquad \text{(voltage divider rule)}$$

Reminder: Elements in Parallel

- ***Two elements, branches, or networks are* in parallel *if they have two points in common***



Reminder: Elements in Parallel



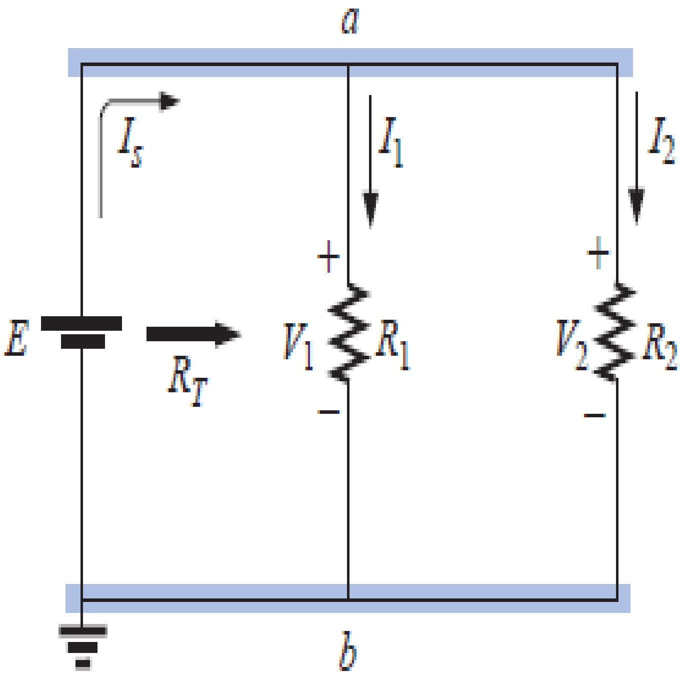
Reminder: Resistors in parallel

- ***For parallel resistors, the total conductance is the sum of the individual conductances.***
- $\boldsymbol{G = \frac{1}{R}}$

$$\boxed{G_T = G_1 + G_2 + G_3 + \cdots + G_N}$$

$$\boxed{\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots + \frac{1}{R_N}}$$

Reminder: Resistors in parallel



The voltage across parallel elements is the same.

$$V_1 = V_2 = E$$

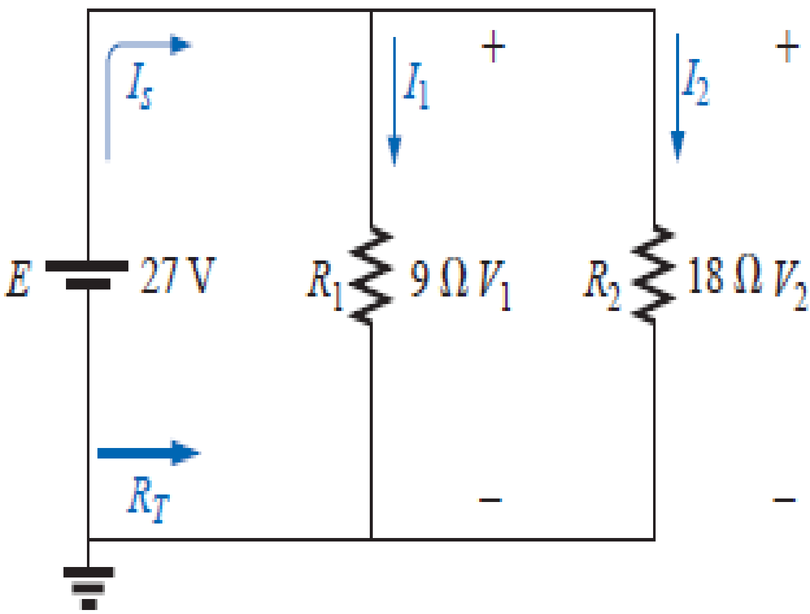
$$I_1 = \frac{V_1}{R_1} = \frac{E}{R_1}$$

$$I_2 = \frac{V_2}{R_2} = \frac{E}{R_2}$$

For single-source parallel networks, the source current (Is) is equal to the sum of the individual branch currents.

$$I_s = I_1 + I_2$$

Question: Resistors in parallel



a. Calculate R_T.

b. Determine I_s.

c. Calculate I_1 and I_2, and demonstrate that $I_s = I_1 + I_2$.

d. Determine the power to each resistive load.

e. Determine the power delivered by the source, and compare it to the total power dissipated by the resistive elements.

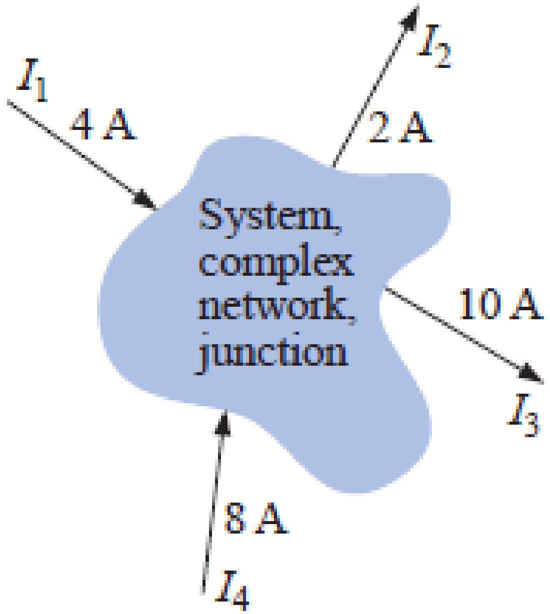
KIRCHHOFF'S CURRENT LAW

- Kirchhoff's current law (KCL) states that the algebraic sum of the currents entering and leaving an area, system, or junction is zero.
- In other words, the sum of the currents entering an area, system, or junction must equal the sum of the currents leaving the area, system, or junction.

$$\boxed{\Sigma I_{\text{entering}} = \Sigma I_{\text{leaving}}}$$

KIRCHHOFF'S CURRENT LAW

$$\Sigma\, I_{\text{entering}} = \Sigma\, I_{\text{leaving}}$$



$$I_1 + I_4 = I_2 + I_3$$
$$4\text{ A} + 8\text{ A} = 2\text{ A} + 10\text{ A}$$
$$12\text{ A} = 12\text{ A}$$

Current Divider Principle

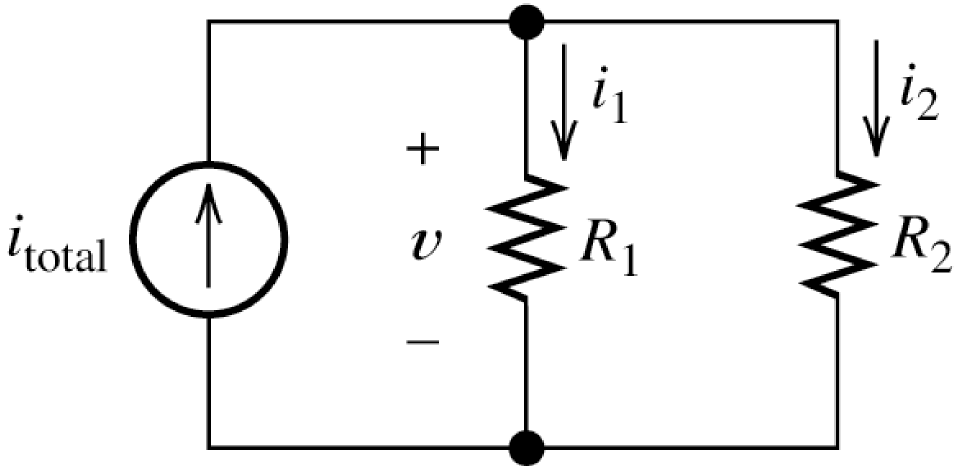
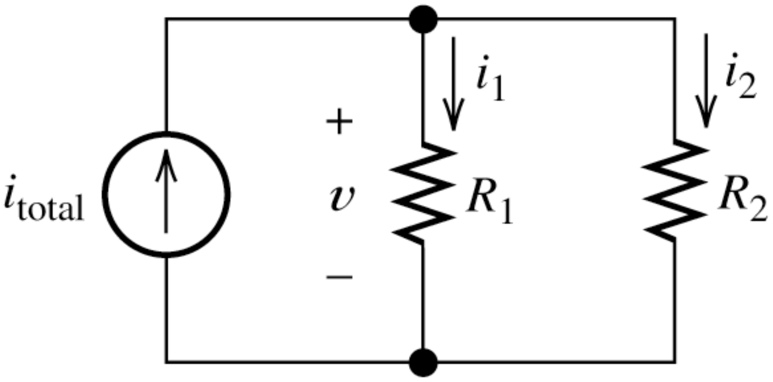


Figure 2.10 Circuit used to derive the current-division principle.

Current Division Principle



$$i_1 = \frac{v}{R_1} = \frac{R_2}{R_1 + R_2} i_{total}$$

$$i_2 = \frac{v}{R_2} = \frac{R_1}{R_1 + R_2} i_{total}$$

It can be also simplified as
(Especially considering
multiple resistors in parallel)

$$\boxed{I_x = \frac{R_T}{R_x} I}$$

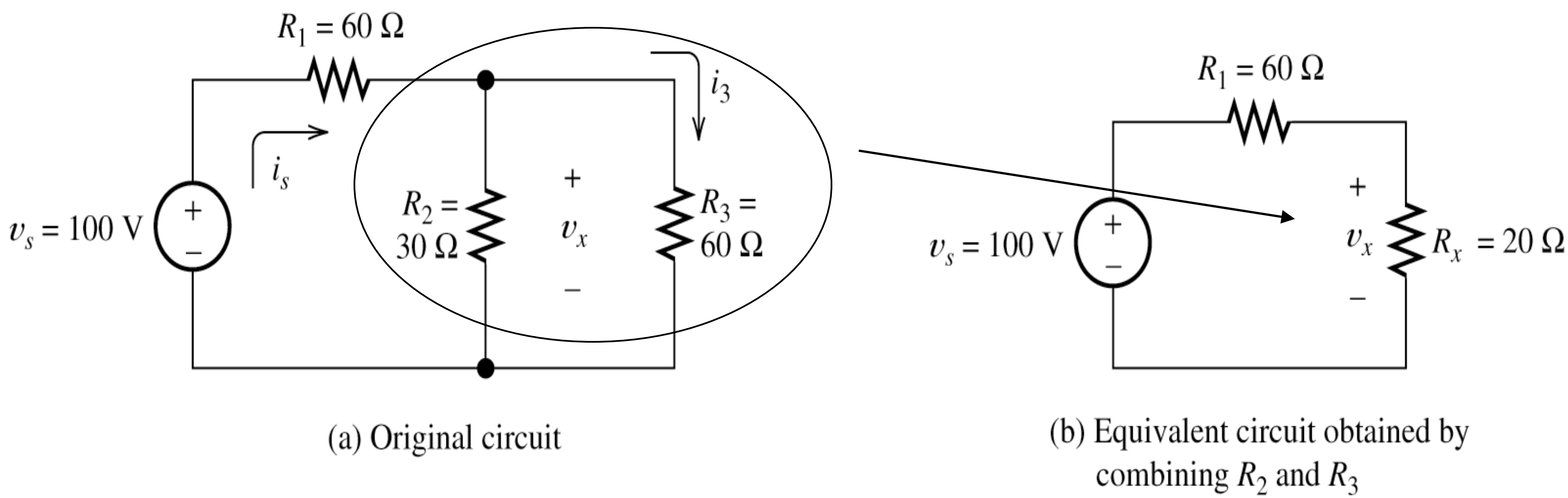


Figure 2.11 Circuit for Example 2.4.

Application of the Current-Division Principle

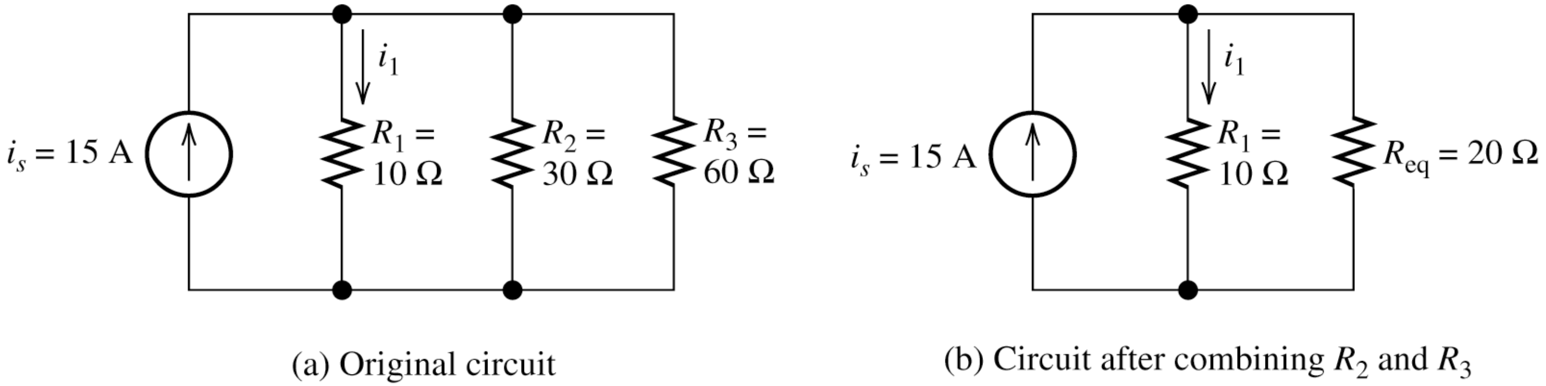


Figure 2.12 Circuit for Example 2.5.

$$R_{eq} = \frac{R_2 R_3}{R_2 + R_3} = \frac{30 \times 60}{30 + 60} = 20\Omega$$

$$i_1 = \frac{R_{eq}}{R_1 + R_{eq}} i_s = \frac{20}{10 + 20} 15 = 10\text{A}$$

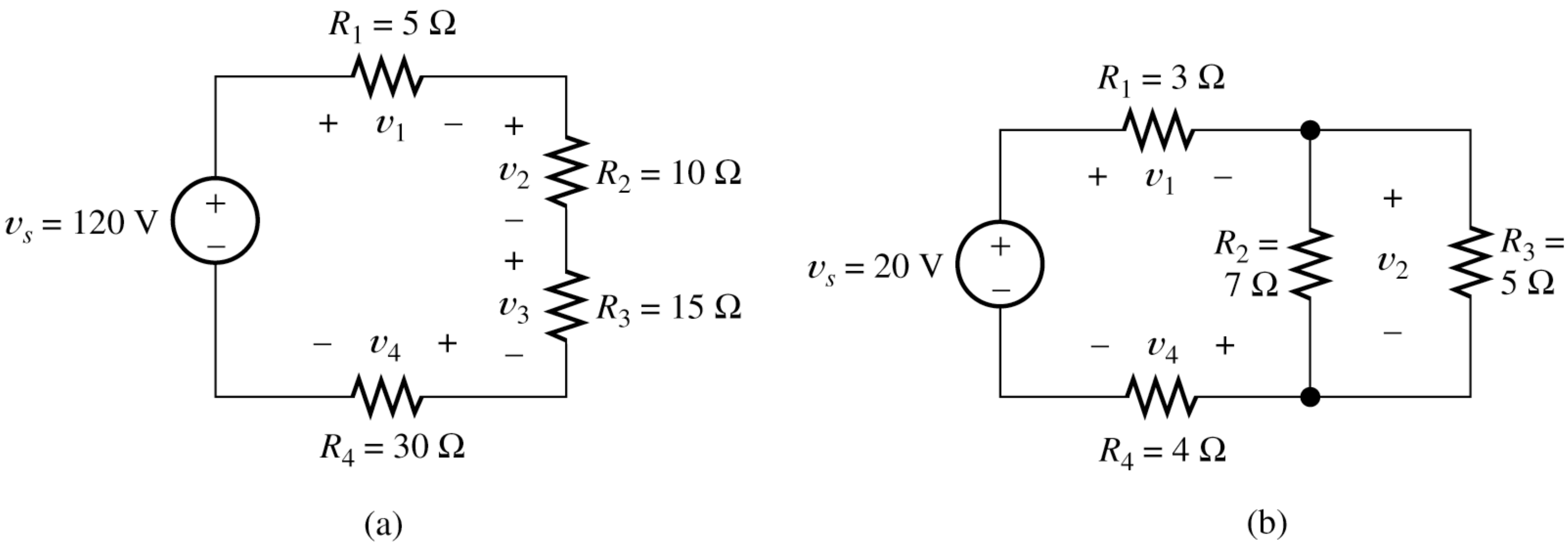


Figure 2.14 Circuits for Exercise 2.3.

- Voltage division

- Voltage division and
- current division

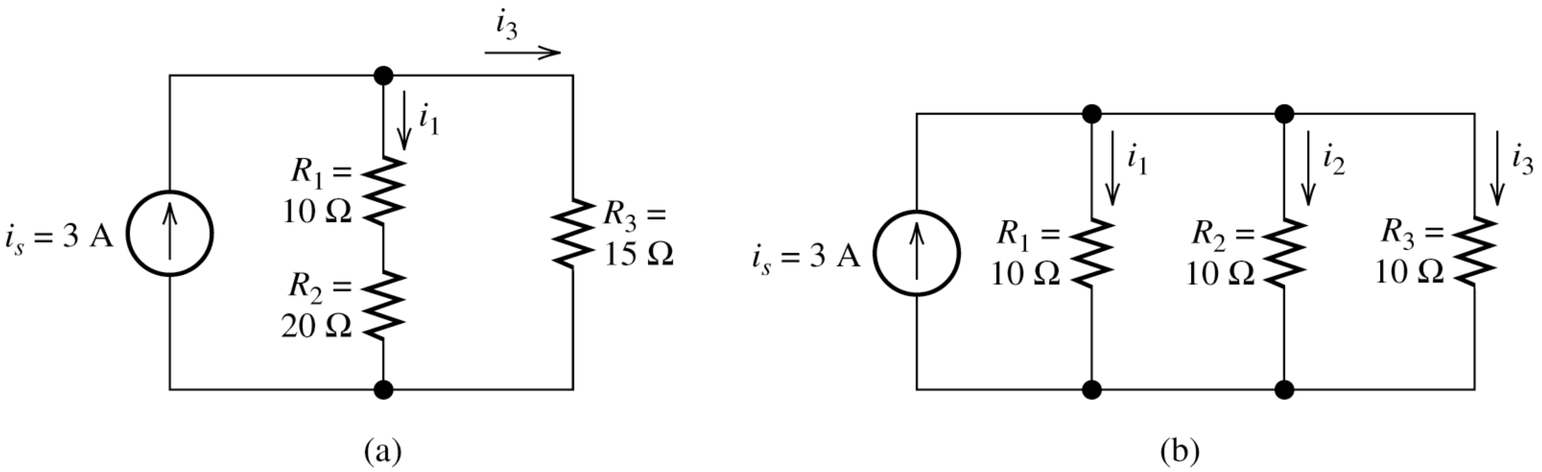


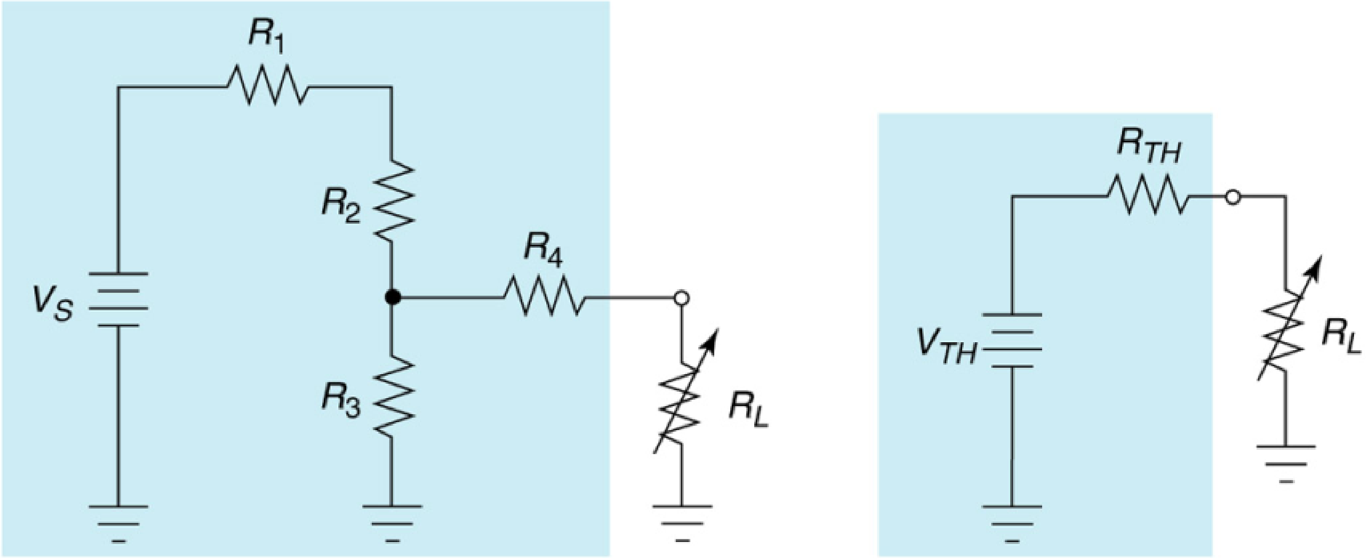
Figure 2.15 Circuits for Exercise 2.4.

- Current division

Although they are very important concepts, series/parallel equivalents and the current/voltage division principles are not sufficient to solve all circuits.

Thevenin's Theorem

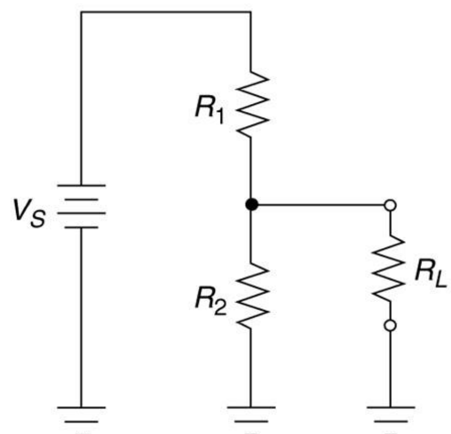
- Thevenin's Theorem – any resistive circuit or network, no matter how complex, can be represented as a voltage source in series with a source resistance



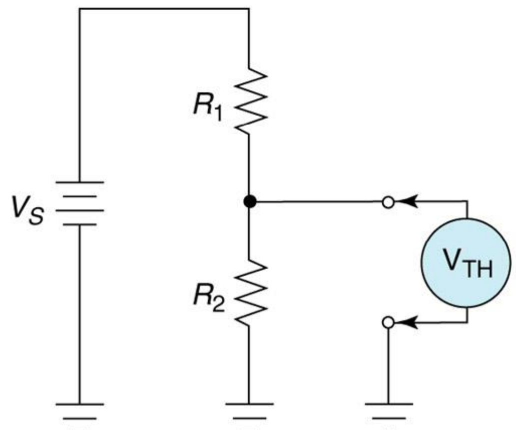
(a) Source circuit (b) Thevenin equivalent

Thevenin's Theorem

- Thevenin Voltage (V_{TH}) – the voltage present at the output terminals of the circuit when the load is removed



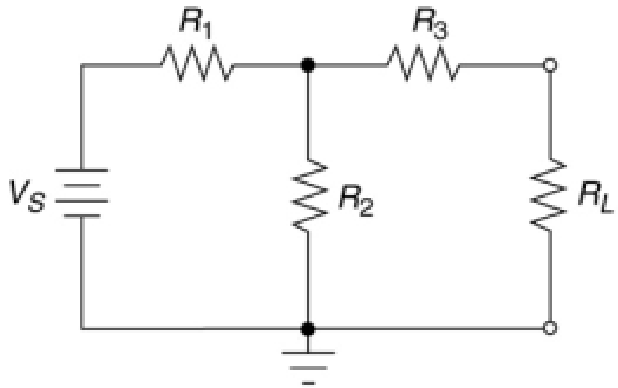
(a) Example circuit



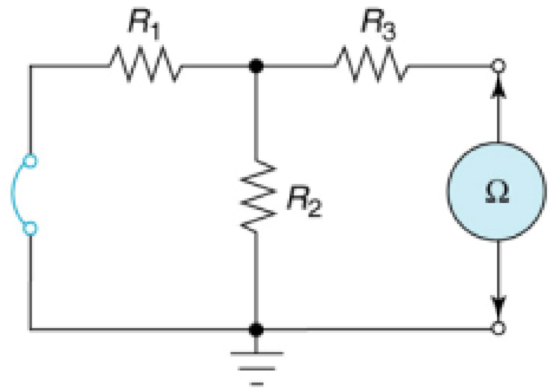
(b) Measuring the Thevenin voltage for the example circuit

Thevenin's Theorem

- Thevenin Resistance (R_{TH}) – the resistance measured across the output terminals with the load removed



(a) Example circuit



(b) Measuring the Thevenin resistance for the example circuit. (*Note:* that the source has been replaced by a jumper wire.)

Thévenin Equivalent Circuits

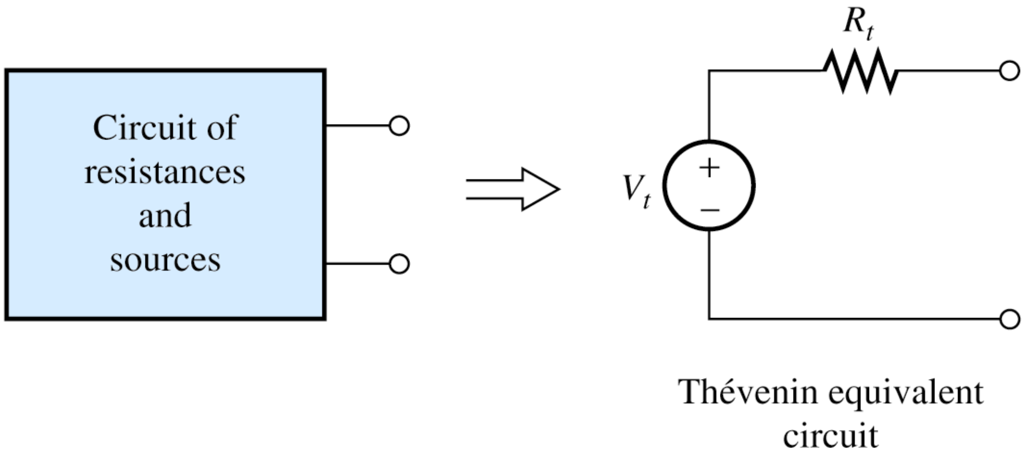


Figure 2.40 A two-terminal circuit consisting of resistances and sources can be replaced by a Thévenin equivalent circuit.

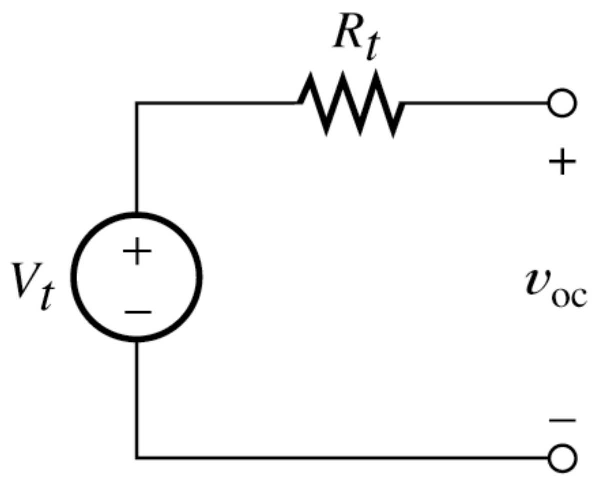


Figure 2.41 Thévenin equivalent circuit with open-circuited terminals. The open-circuit voltage v_{oc} is equal to the Thévenin voltage V_t.

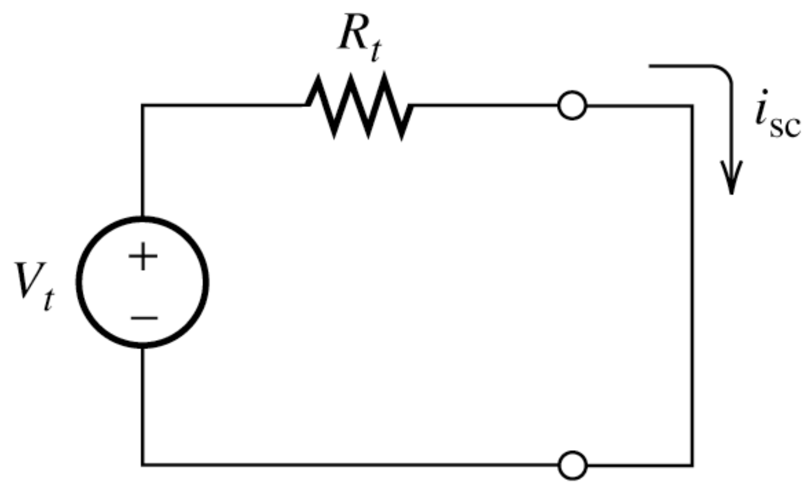
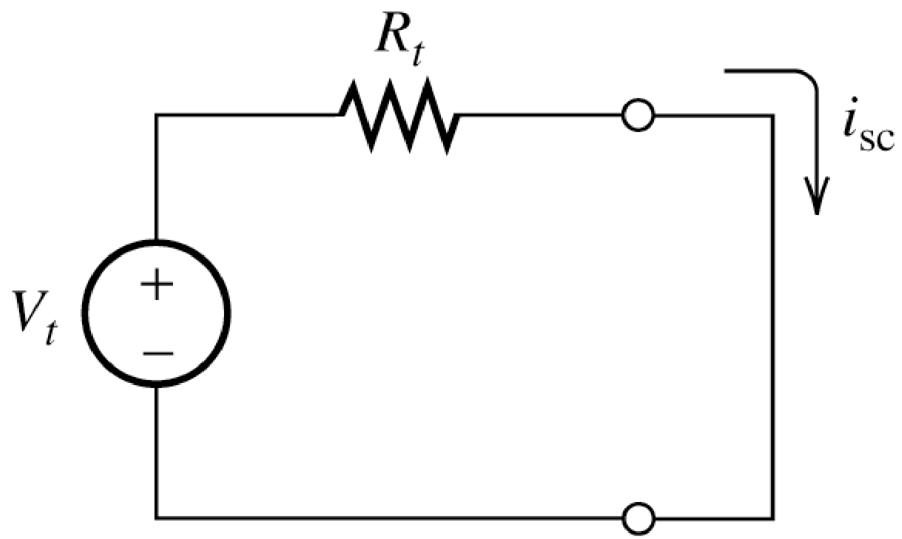


Figure 2.42 Thévenin equivalent circuit with short-circuited terminals. The short-circuit current is $i_{sc} = V_t/R_t$.

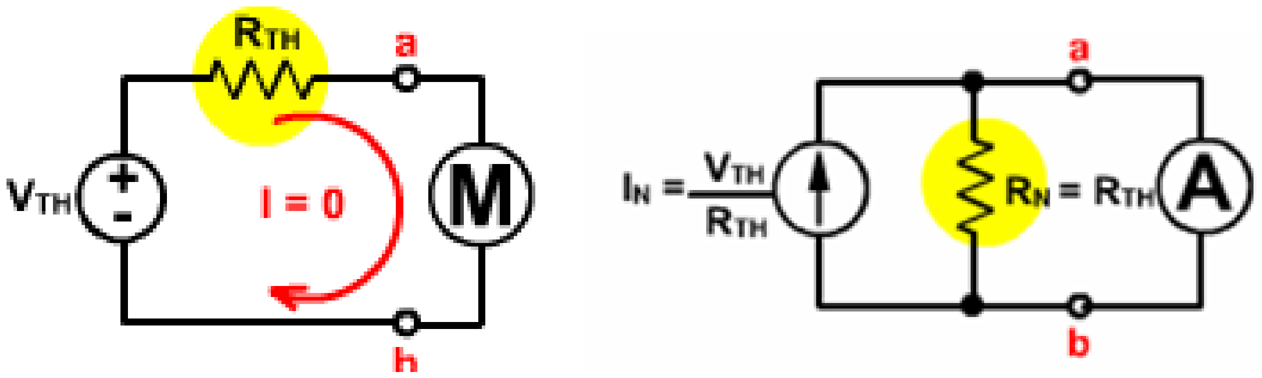
Thévenin Equivalent Circuits



$$V_t = v_{oc}$$

$$R_t = \frac{v_{oc}}{i_{sc}}$$

Thévenin Equivalent Circuits



1. Connect a voltmeter to the box

   Meter measured V_{TH}, since $I = 0$

2. Connect an ammeter to the box

   Meter measured $I_N = \left(\frac{V_{TH}}{R_{TH}}\right)$

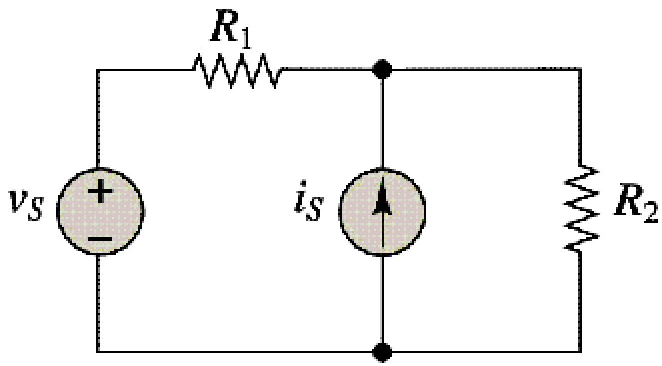
3. $R_{TH} = \dfrac{V_{MEASURED}}{I_{MEASURED}}$

Finding the Thévenin Resistance Directly

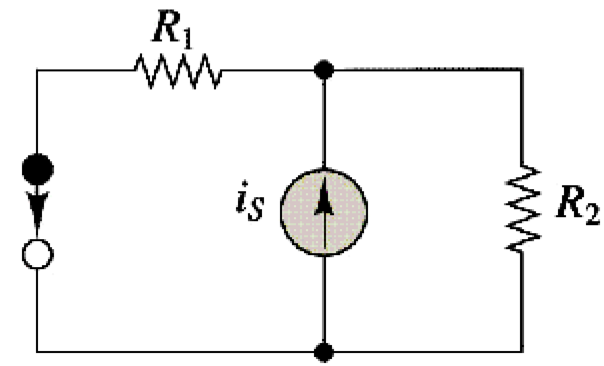
When **zeroing a voltage source**, it becomes a short circuit. When **zeroing a current source**, it becomes an open circuit.

We can find the Thévenin resistance by ***zeroing the sources in the original network*** *and then computing the resistance between the terminals.*

1. In order to set a voltage source equal to zero, we replace it with a short circuit.

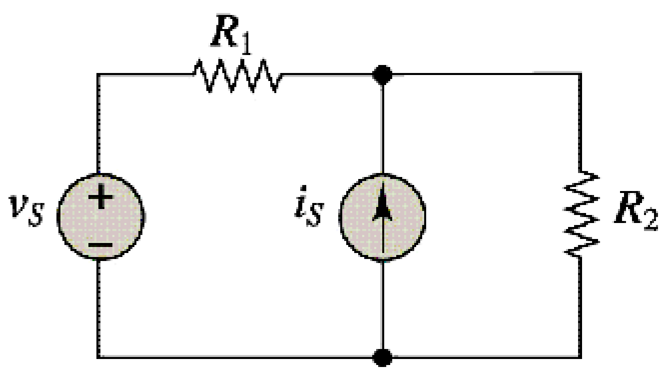


A circuit

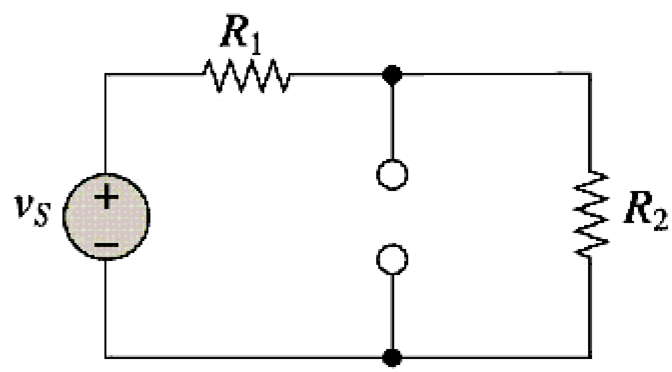


The same circuit with $v_S = 0$

2. In order to set a current source equal to zero, we replace it with an open circuit.



A circuit



The same circuit with $i_S = 0$

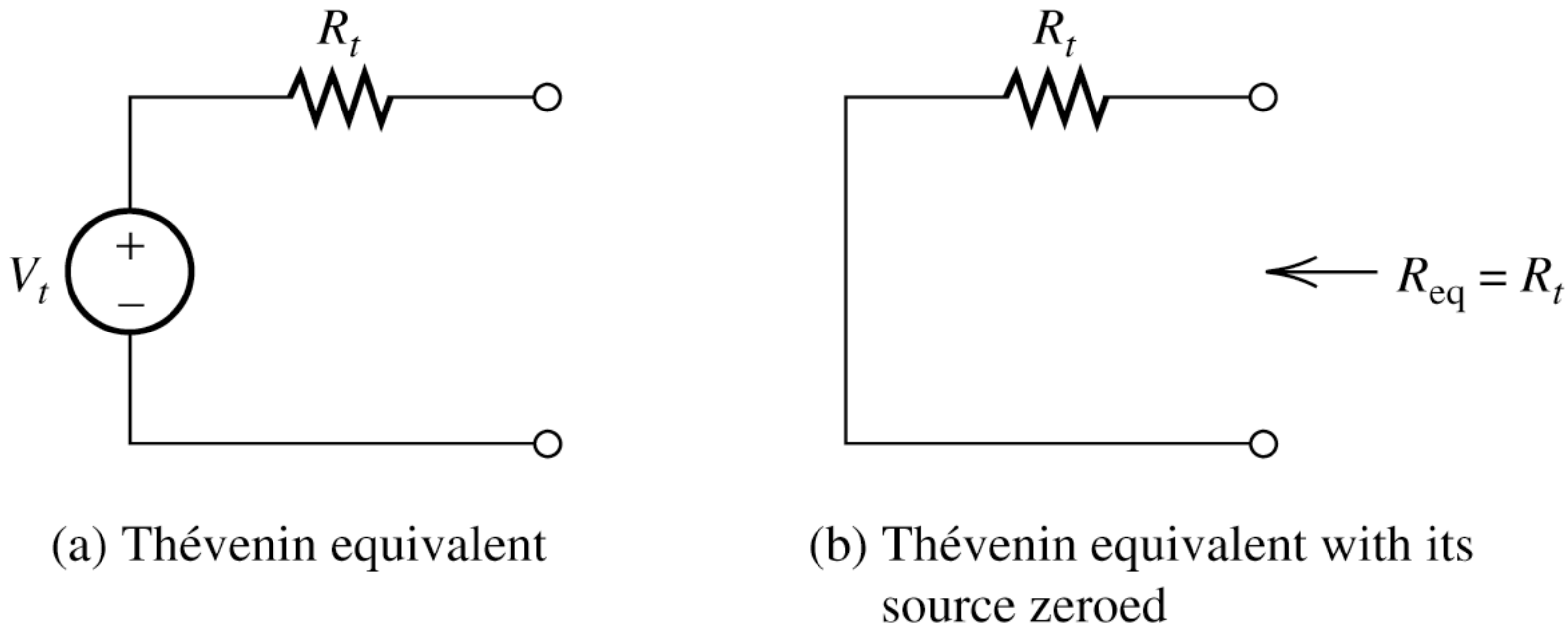
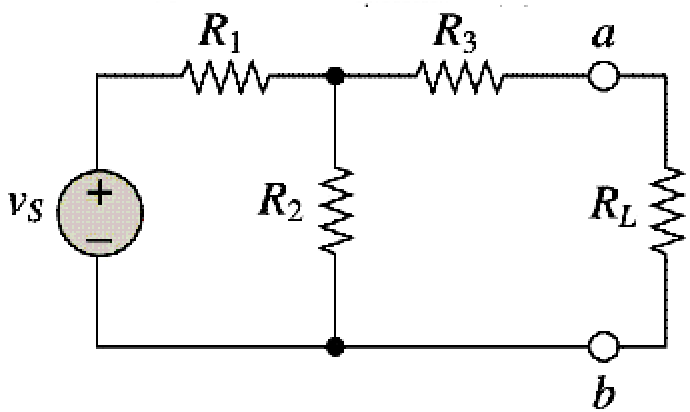
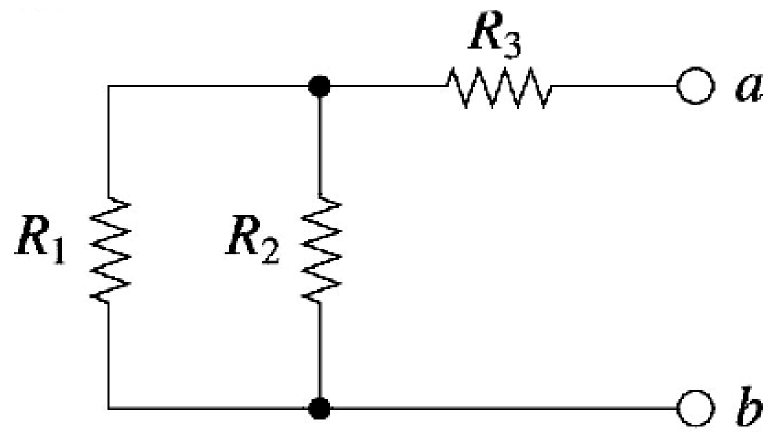


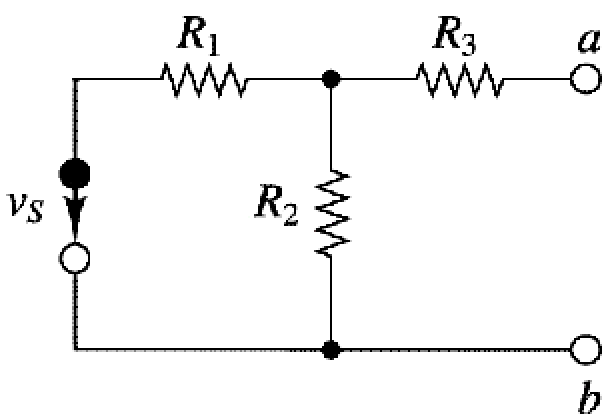
Figure 2.45 When the source is zeroed, the resistance seen from the circuit terminals is equal to the Thévenin resistance.

Computation of Thevenin resistance

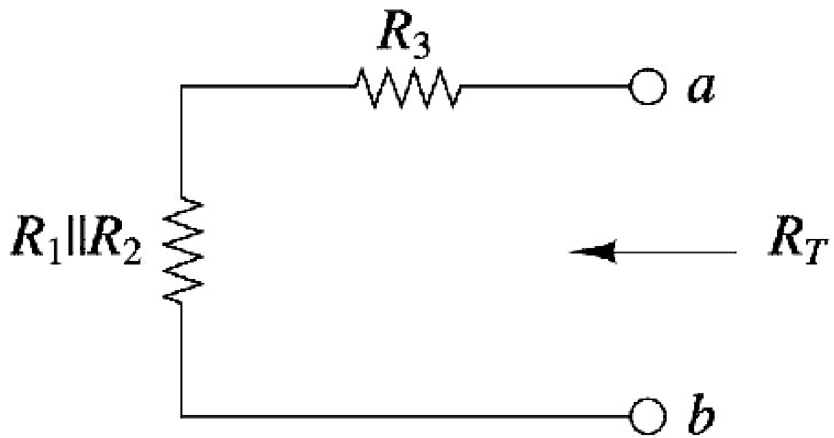


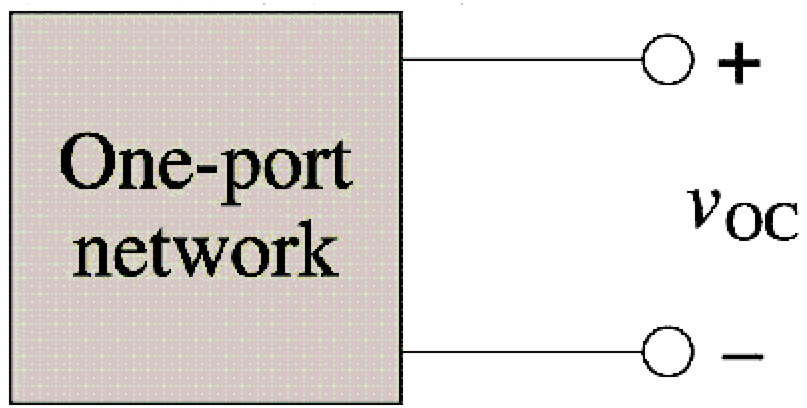
Complete circuit

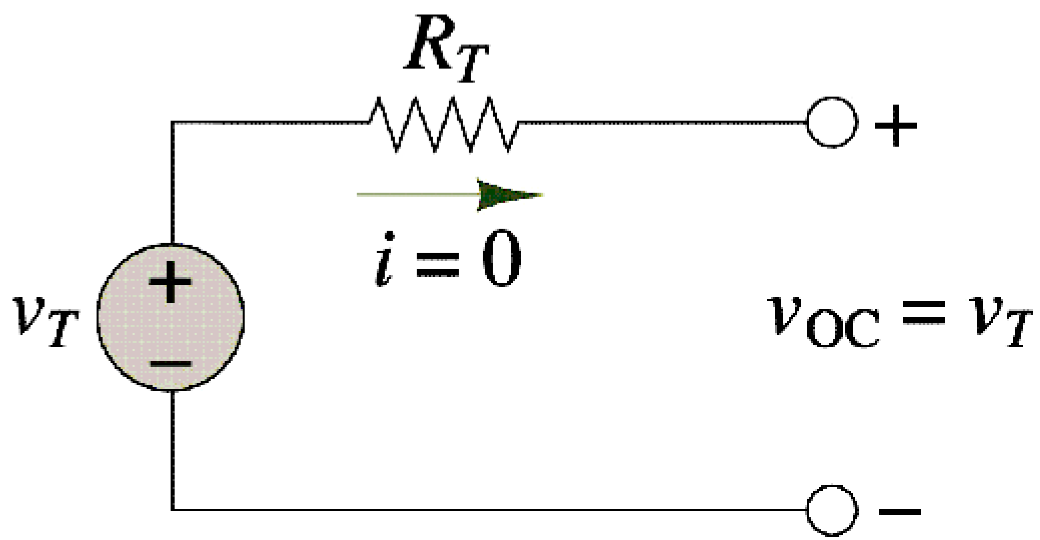




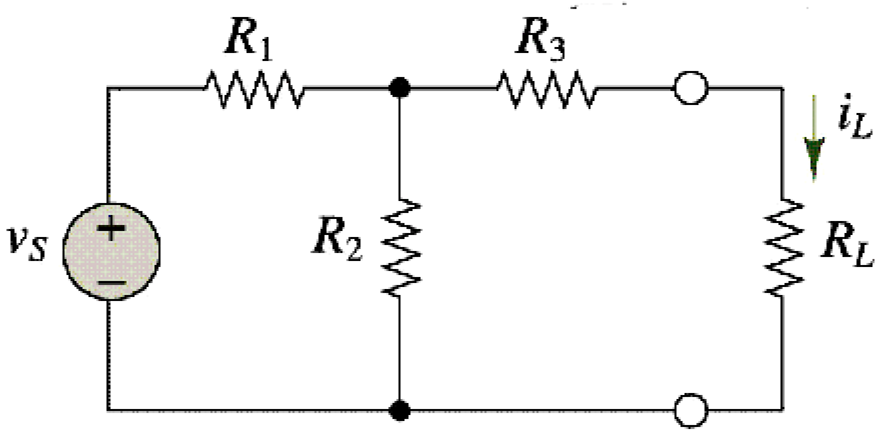
Circuit with load removed
for computation of R_T. The voltage
source is replaced by a short circuit.



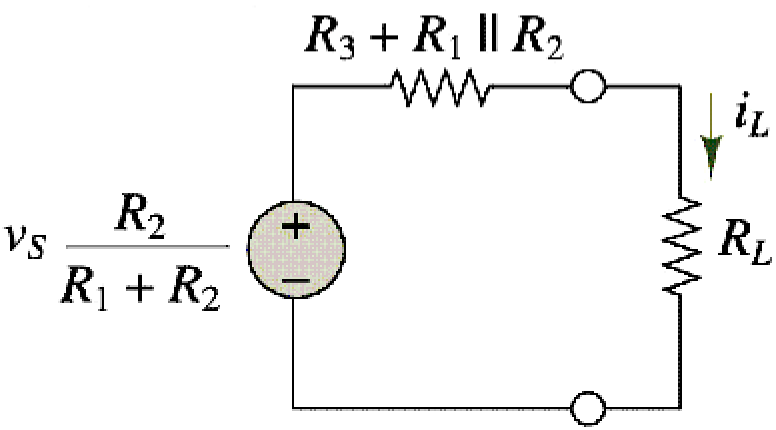

One-port network
+
v_{OC}
–


R_T
+
$i = 0$
v_T
+
–
$v_{OC} = v_T$
–

A circuit and its Thévenin equivalent



A circuit



Its Thévenin equivalent

Applications of Thevenin's Theorem

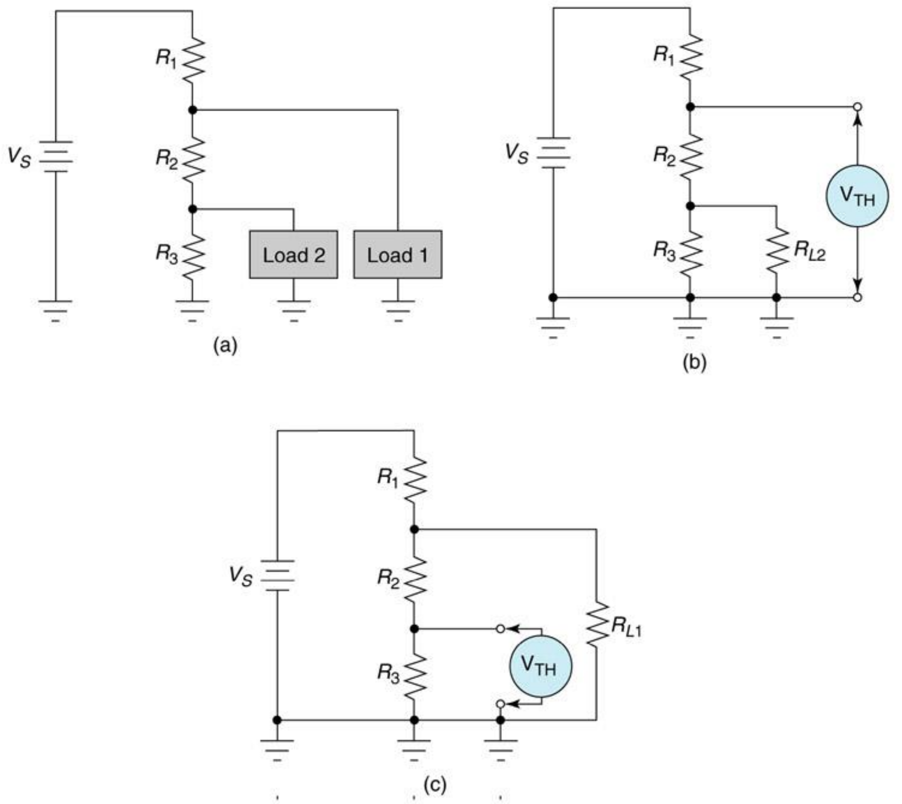
- Load Voltage Ranges – Thevenin's theorem is most commonly used to predict the change in load voltage that will result from a change in load resistance

Applications of Thevenin's Theorem

- Maximum Power Transfer
  - Maximum power transfer from a circuit to a variable load occurs when the load resistance equals the source resistance
  - For a series-parallel circuit, maximum power occurs when $R_L = R_{TH}$

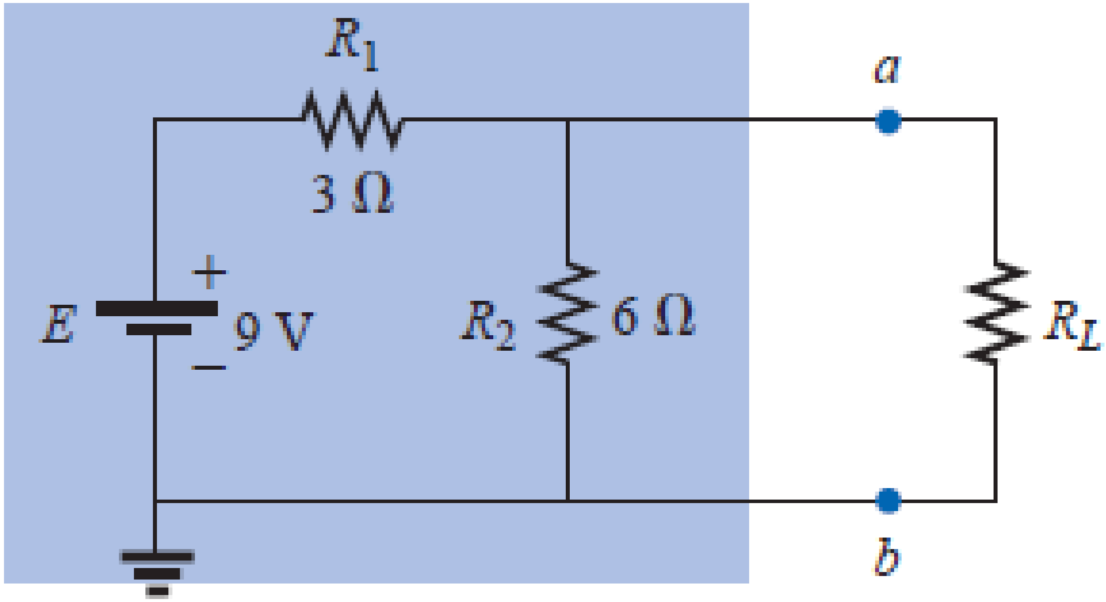
Applications of Thevenin's Theorem

- Multiload Circuits



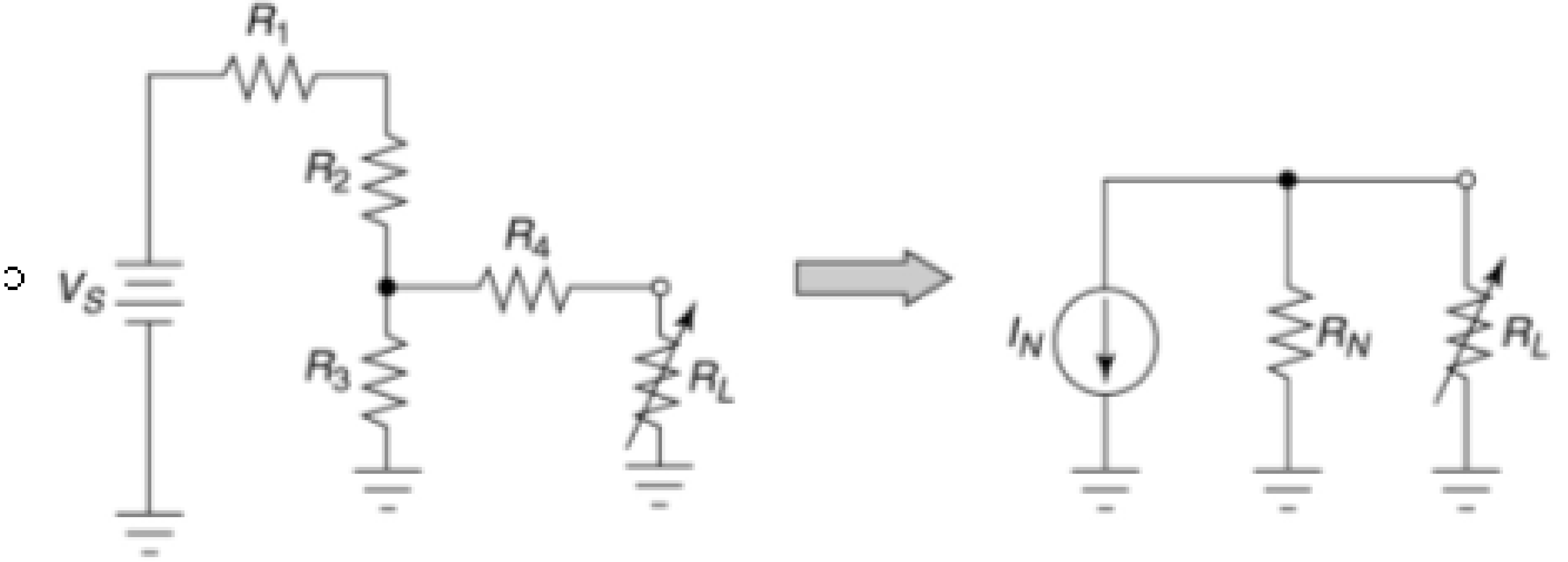
Applications of Thevenin's Theorem

- Example: Find the Thevenin equivalent circuit for the network in the shaded area of the circuit below



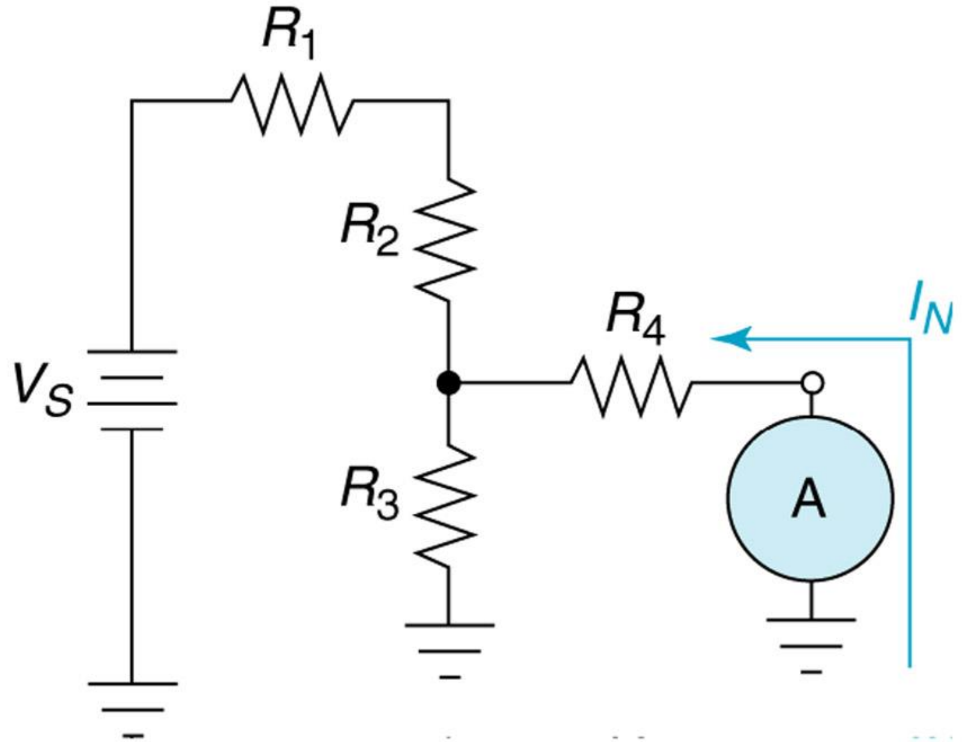
Norton’s Theorem

- Norton’s Theorem – any resistive circuit or network, no matter how complex, can be represented as a current source in parallel with a source resistance

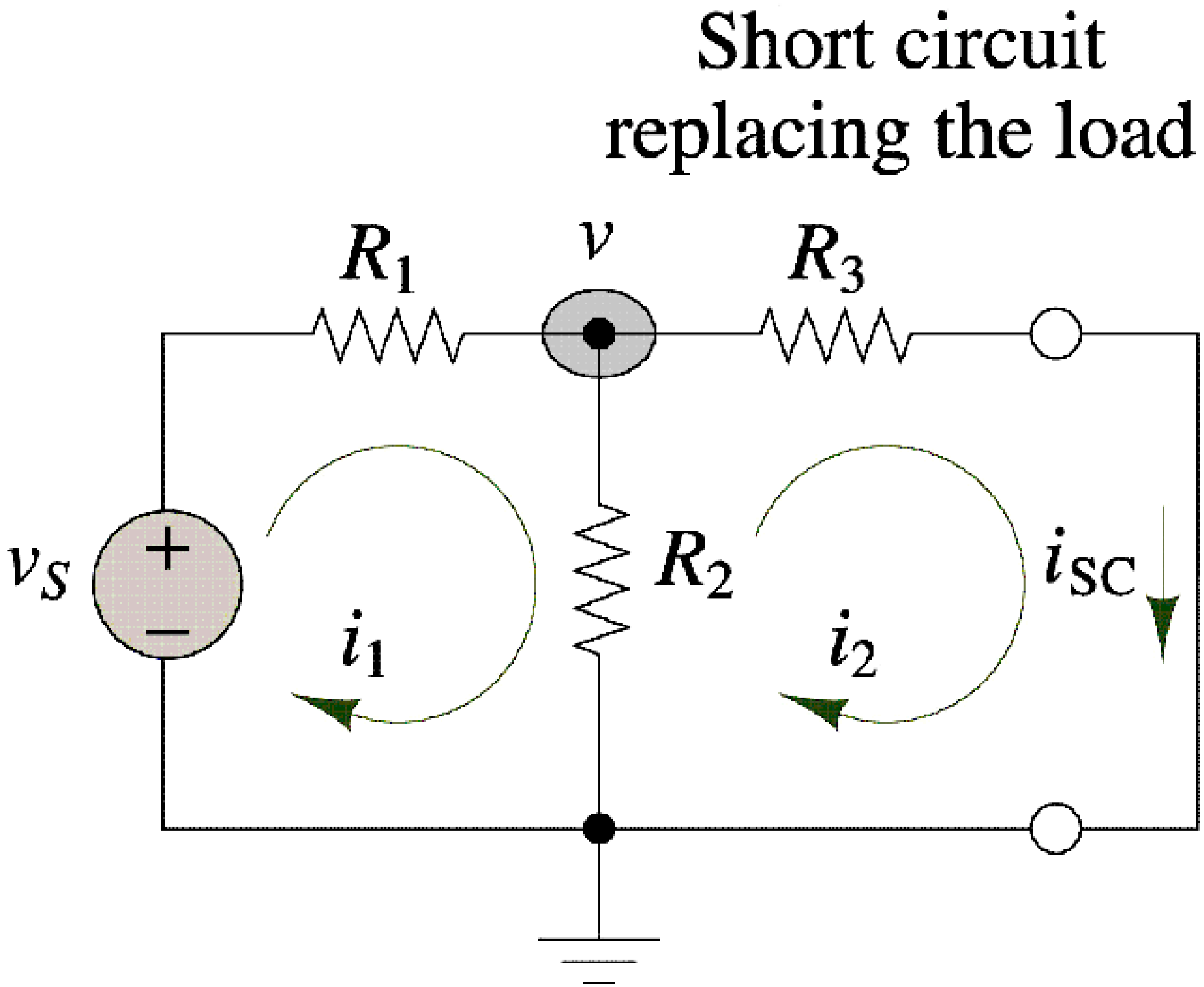


Norton's Theorem

- Norton Current (I_N) – the current through the shorted load terminals



Computation of Norton current

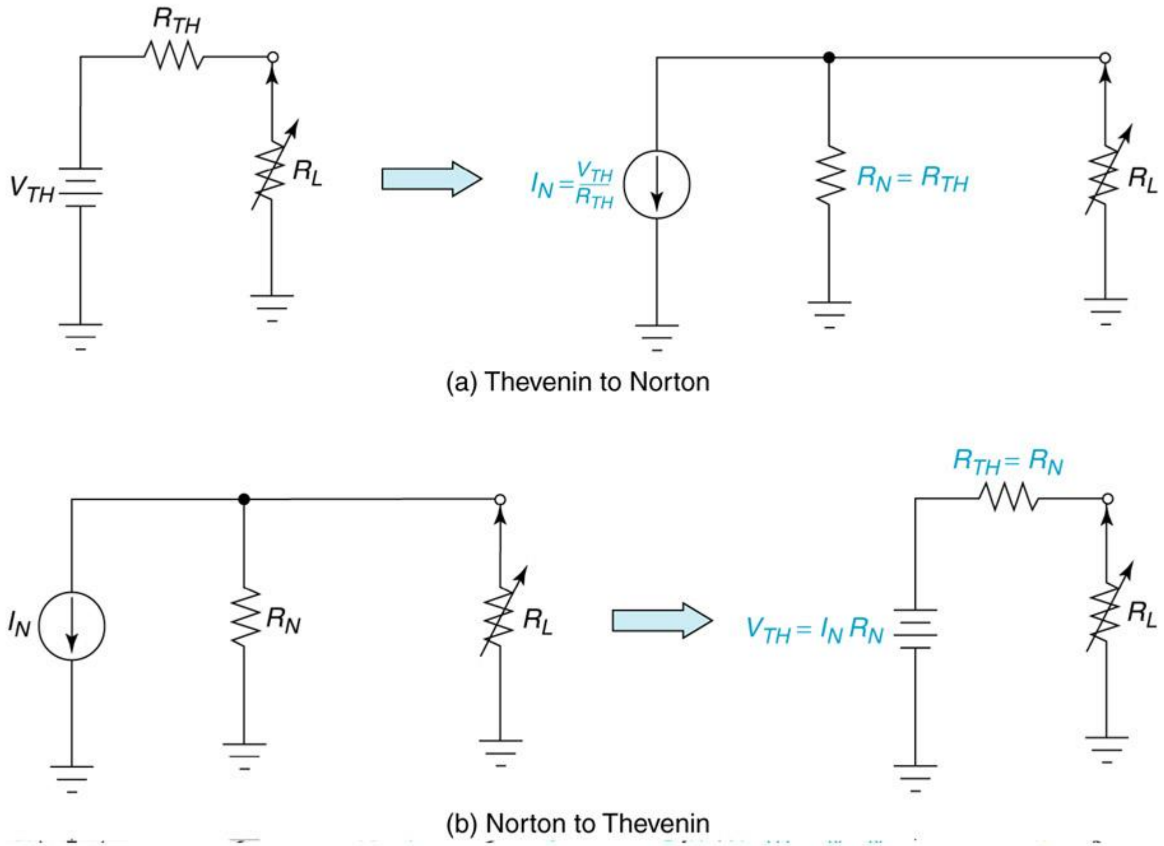


Norton's Theorem

- Norton Resistance (R_N) – the resistance measured across the open load terminals (measured and calculated exactly like R_{TH})

Norton’s Theorem

- Norton-to-Thevenin and Thevenin-to-Norton Conversions



Step-by-step Thévenin/Norton-Equivalent-Circuit Analysis

1. Perform two of these:

a. Determine the open-circuit voltage $V_t = v_{\text{oc}}$.

b. Determine the short-circuit current $I_n = i_{\text{sc}}$.

c. Zero the sources and find the Thévenin resistance R_t looking back into the terminals.

2. Use the equation $V_t = R_t\, I_n$ to compute the remaining value.

3. The Thévenin equivalent consists of a voltage source V_t in series with R_t .

4. The Norton equivalent consists of a current source I_n in parallel with R_t.

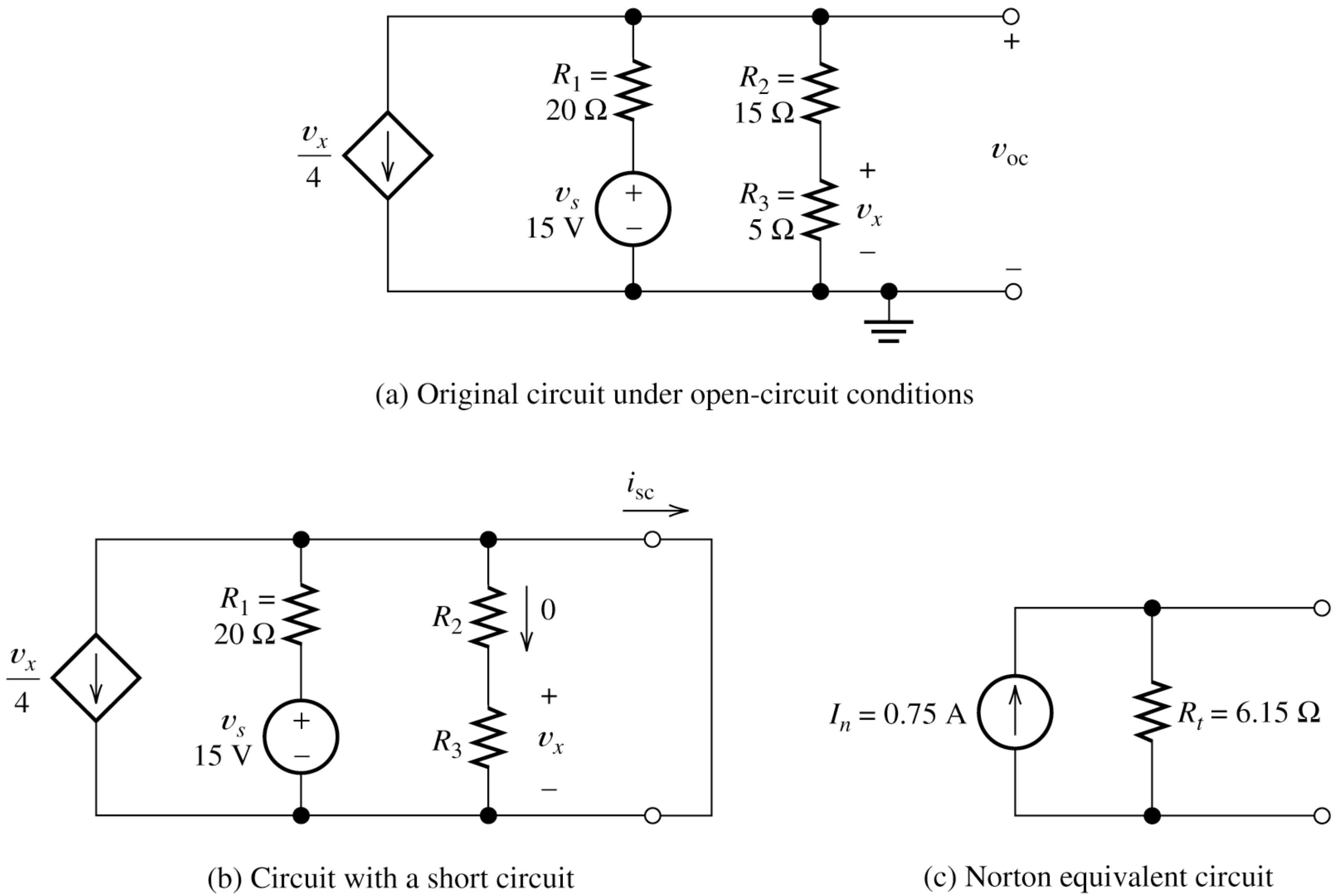
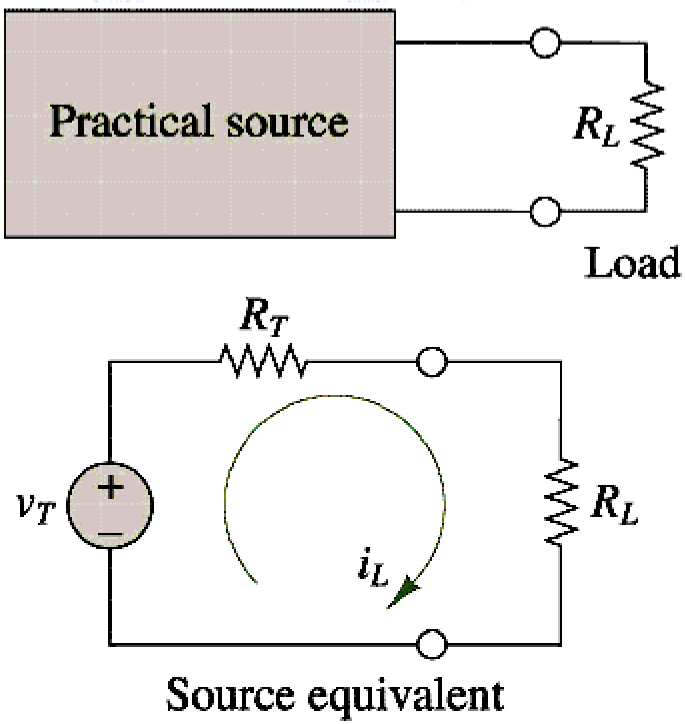


Figure 2.51 Circuit of Example 2.17.

Maximum Power Transfer

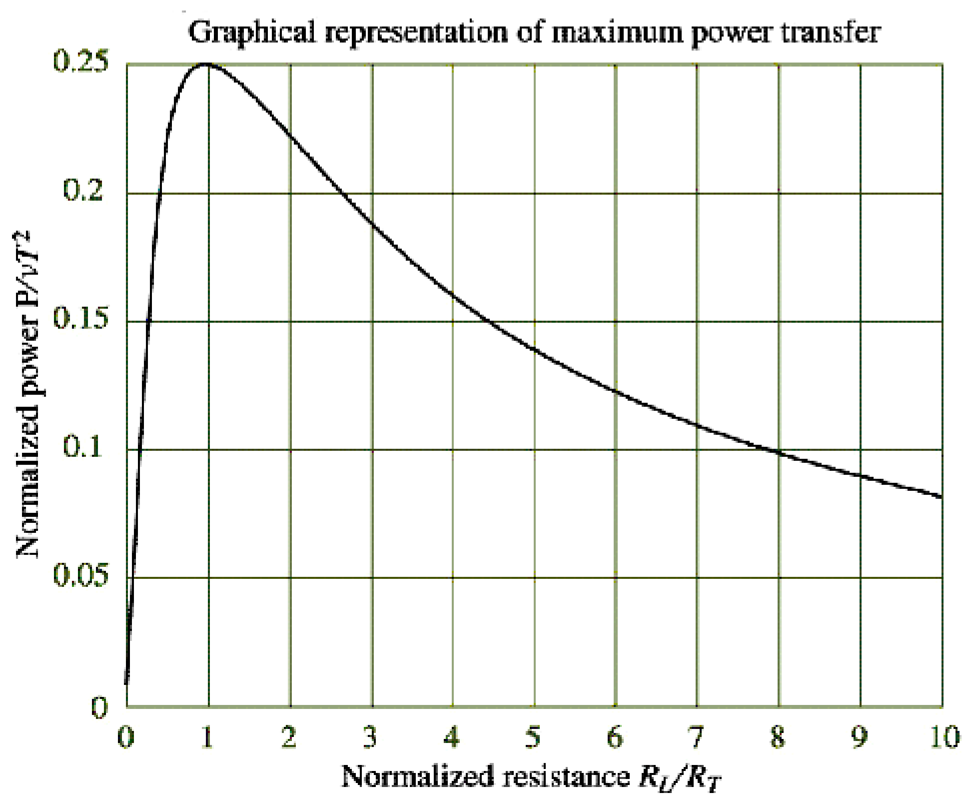
The load resistance that absorbs the maximum power from a two-terminal circuit is equal to the Thévenin resistance.

Power transfer between source and load



Given v_T and R_T, what value of R_L will allow for maximum power transfer?

Graphical representation of maximum power transfer



…that's all folks…
…thanks for your time…