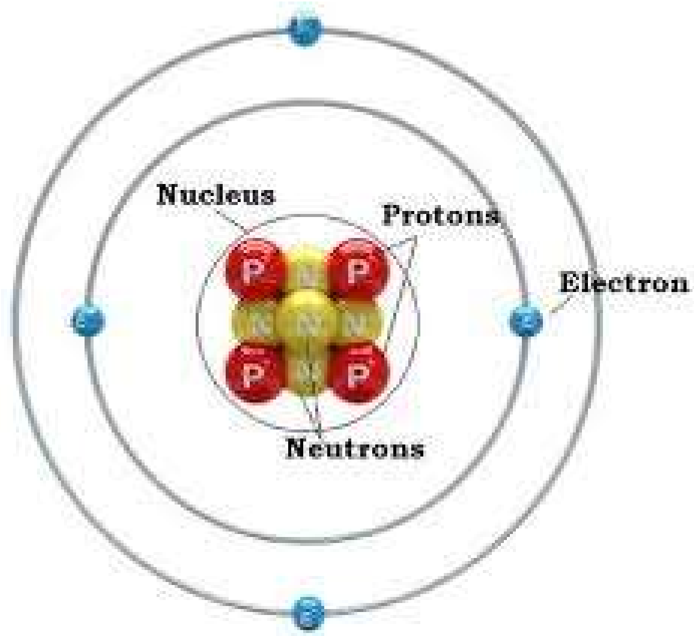
Element III

Electrical and Electronic Principles

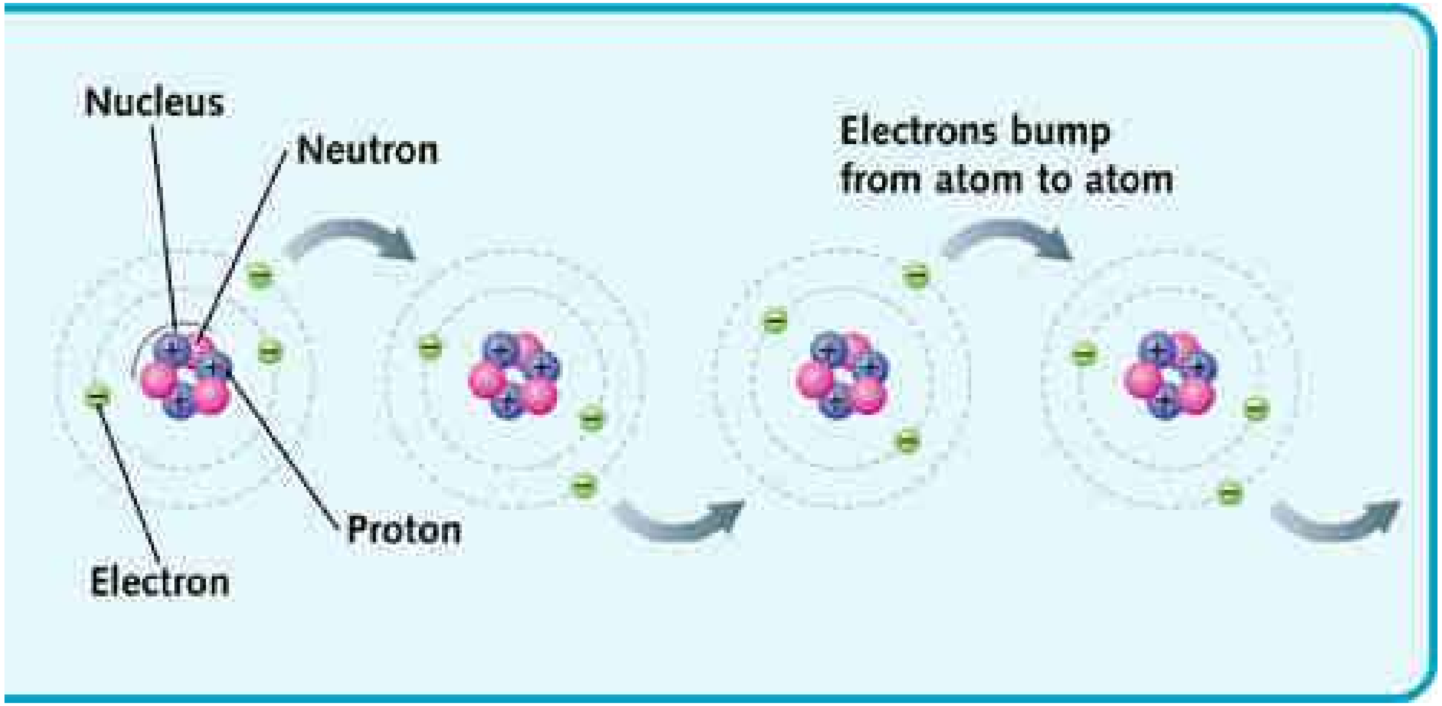
BASIC CONCEPTS OF ELECTRICITY

- Matter
  - That which occupies space and possesses rest mass (weight); can be solid, liquid, or gas
  - Are made up of atoms, which in turn are made up of protons (+), neutrons (neutral) and electrons (-)



BASIC CONCEPTS OF ELECTRICITY

- Electric current is a flow of electric charge, often carried by moving electrons
  - Coulomb - A unit of electrical charge; the quantity of electricity passing in one second through a circuit in which the rate of flow is one ampere

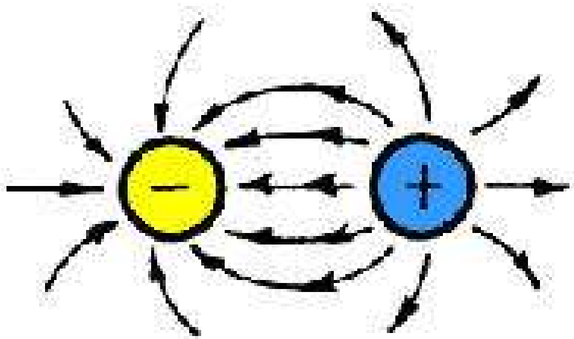


BASIC CONCEPTS OF ELECTRICITY

- Electrical Properties of Matter
  - Conductor – outer electrons are "loose"; electric current can flow freely (e.g., silver, copper, most metals)
  - Insulator – outer electrons are "tight"; electric current cannot flow freely (e.g., wood, plastic, rubber)
  - Semi-conductor – a solid substance whose electrical properties is half-way between a conductor and an insulator (e.g., silicon, germanium)
    - Can be made to conduct by the introduction of "impurities"

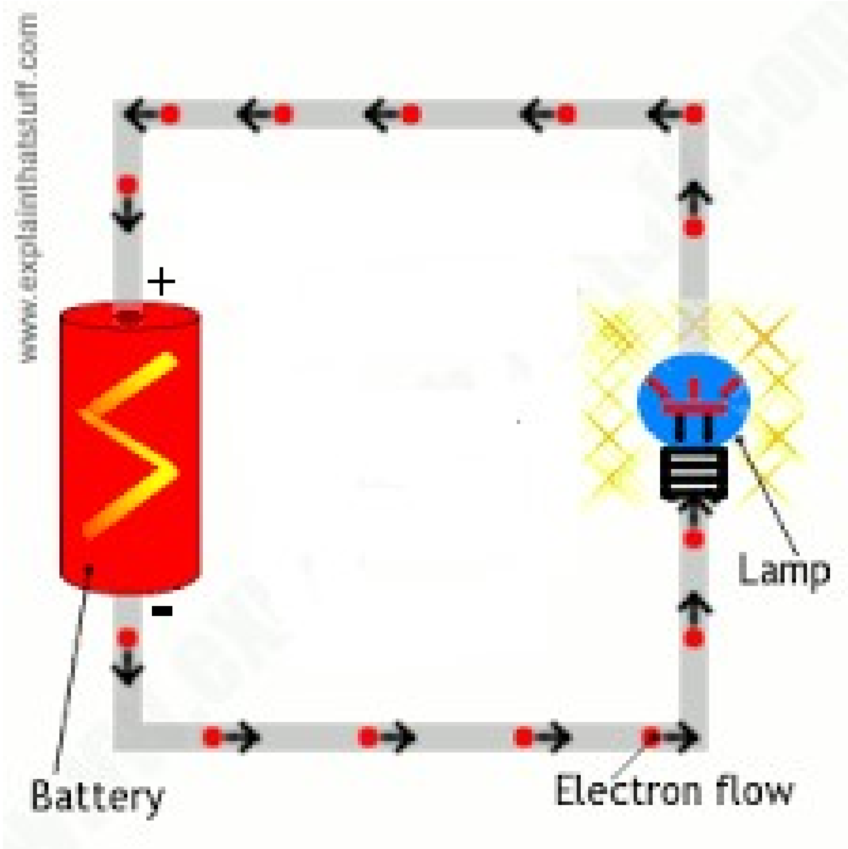
BASIC CONCEPTS OF ELECTRICITY

- "Like charges repel, and unlike charges attract"
  - Electron will repel another electron
  - Protons attract electrons
  - If two oppositely-charged bodies are separated by a small distance, an attractive force is set up between them which is known as "electric field". Any free charge placed between will move.



BASIC CONCEPTS OF ELECTRICITY

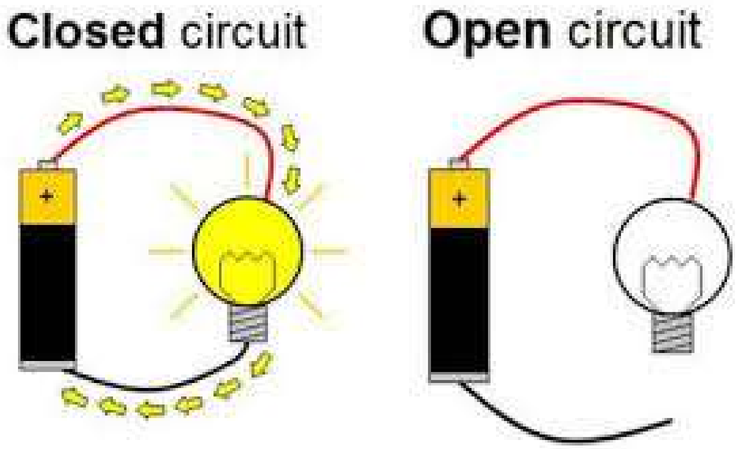
- Electricity is the flow of electrons around a circuit.
  - The negative battery terminal "pushes" the electrons in the wire
  - The electrons move toward the positive terminal
  - As electrons pass through the lamp, energy is dissipated as light



BASIC CONCEPTS OF ELECTRICITY

- When electrons are able to flow, the circuit is said be “closed”, and electric current is greater than 0.

- When electrons are unable to flow, the circuit is said be “open”, and electric current is equal to 0.



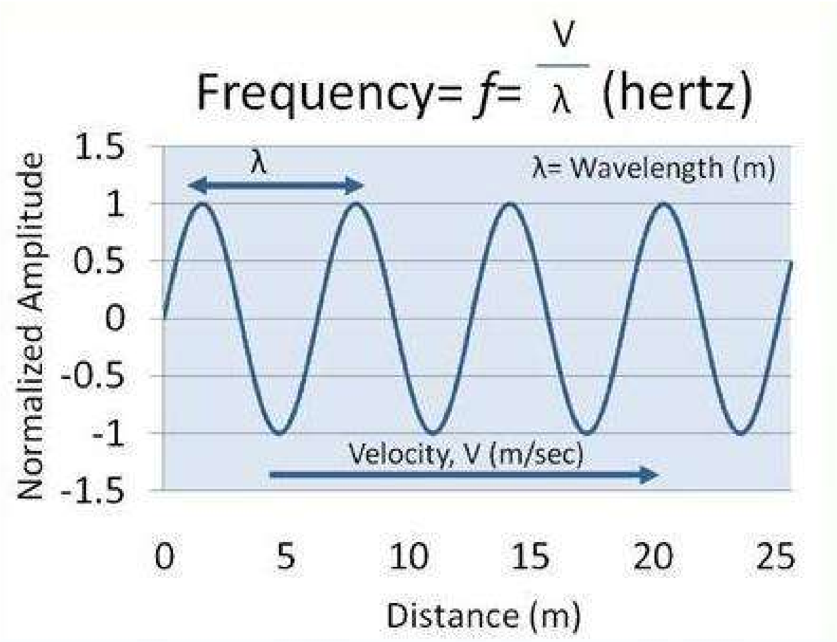
BASIC CONCEPTS OF ELECTRICITY

- Polarity - represents the electrical potential at the ends of a circuit; determines the direction of current flow in a circuit
  - A terminal could be positive (+) or negative (-)
  - Current flow is from positive to negative terminal (a.k.a. conventional current flow)
  - Could be fixed (DC) or alternating (AC)

- Frequency – the number of times a signal changes polarity per second
  - Measured in hertz (Hz)
  - Represented by ***f*** in equations

BASIC CONCEPTS OF ELECTRICITY

- Wavelength - the distance from one peak of the wave's electric field (wave's peak/crest) to the next
  - Inversely proportional to the frequency of the wave
  - The distance a radio wave travels in one second, in a vacuum, is approximately 300,000,000 meters, which is the wavelength of a 1 hertz radio signal.



For radio waves, v = 300,000,000.

$$\lambda(\text{meters}) = \frac{300{,}000{,}000}{f\ (\text{Hz})}$$

BASIC CONCEPTS OF ELECTRICITY

- Example: What is the wavelength of a radio signal with a frequency of 75 MHz?

  λ = 300,000,000 / f (Hz)

  λ = 300,000,000 / 75,000,000 Hz = 4 meters

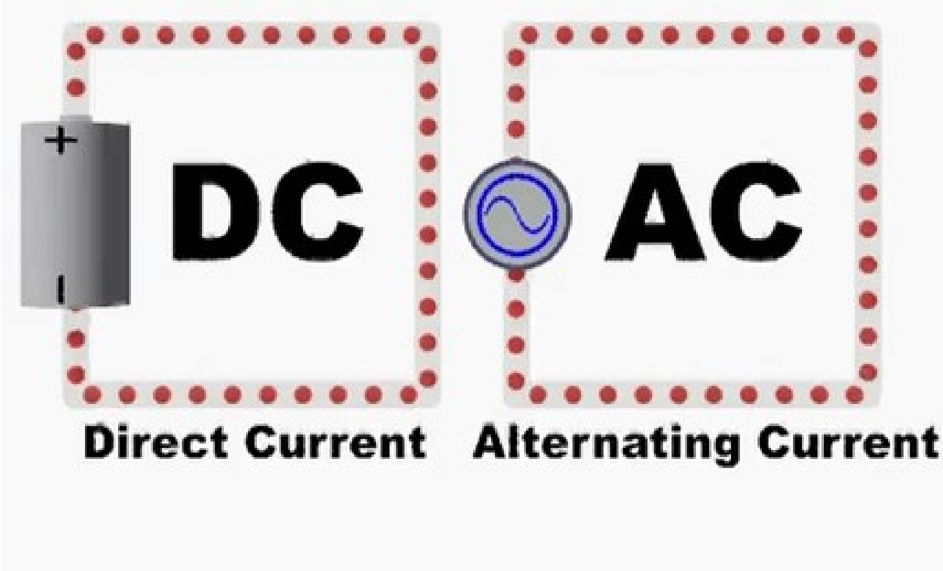
- Example: What is the frequency of a radio signal with a wavelength of 15 meters?

  f = 300,000,000 / λ (meters)

  λ = 300,000,000 / 15 meters = 20,000,000 Hz = ? MHz

BASIC CONCEPTS OF ELECTRICITY

- Current - the movement of electrical charge
  - Measured in amperes, or "amps" (A)
  - Represented by the letter ***I*** in equations
  - Types:
    - Direct current (DC) – electrons flow in one direction only
    - Alternating current (AC) - electrons flow in two directions, first in one direction, then in the opposite direction



BASIC CONCEPTS OF ELECTRICITY

- Voltage - the force of attraction or repulsion between electrically-charged regions
  - Measured in volts (V)
  - Represented by the letter ***V or E*** in equations
  - Types:
    - DC voltage (fixed polarity)
    - AC voltage (polarity changes alternately many times per second)

BASIC CONCEPTS OF ELECTRICITY

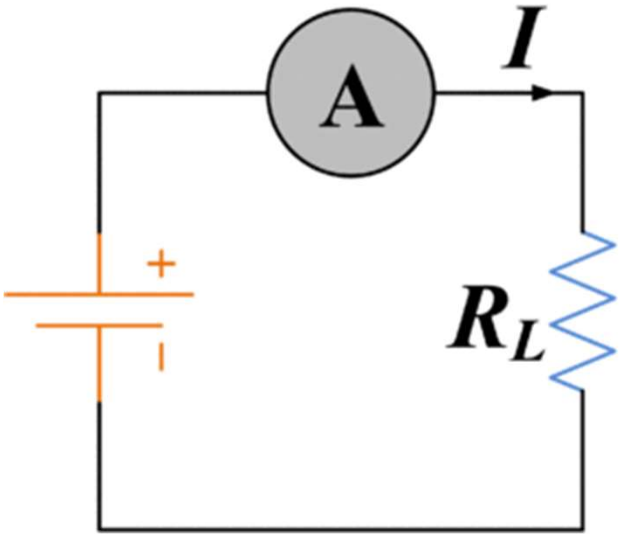
- Resistance – the opposition of a material to the flow of electric current (movement of electrons)
  - Measured in ohms (Ω)
  - Represented by the letter ***R*** in equations

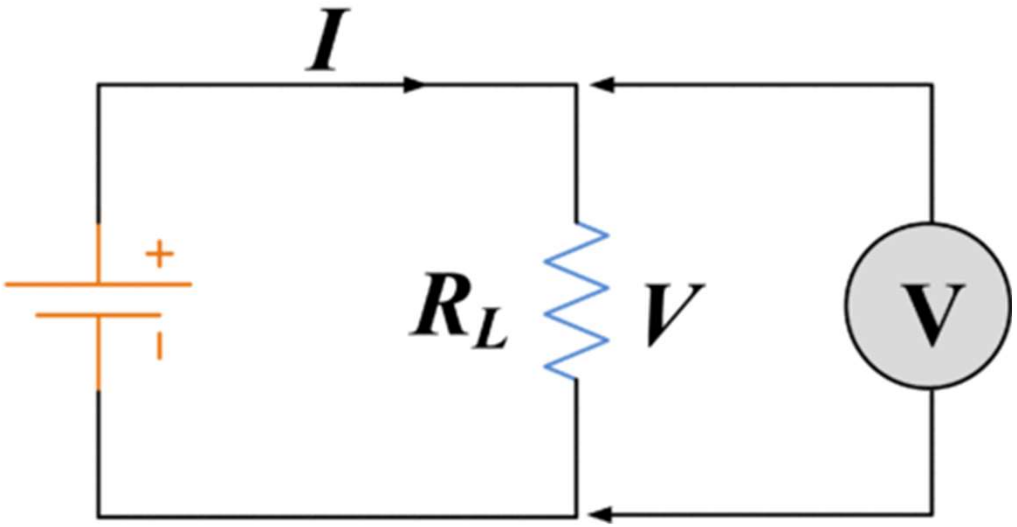
- Conductance – the ability of a material to allow the flow of electric current (movement of electrons)
  - The reverse of resistance
  - Measured in siemens (mho)
  - Represented by the letter ***G*** in equations, G = 1 / R

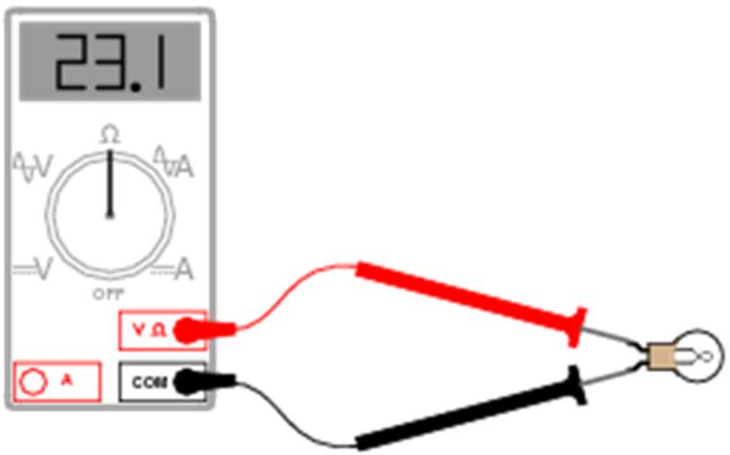
TEST INSTRUMENTS

- Voltmeter – used to measure voltage; connected in parallel to the component
- Ammeter – used to measure current; connected in series to the component
- Ohmmeter – used to measure resistance; connected in parallel to the component while not connected to a circuit
- Wattmeter – used to measure power; typically inserted between source and load

TEST INSTRUMENTS

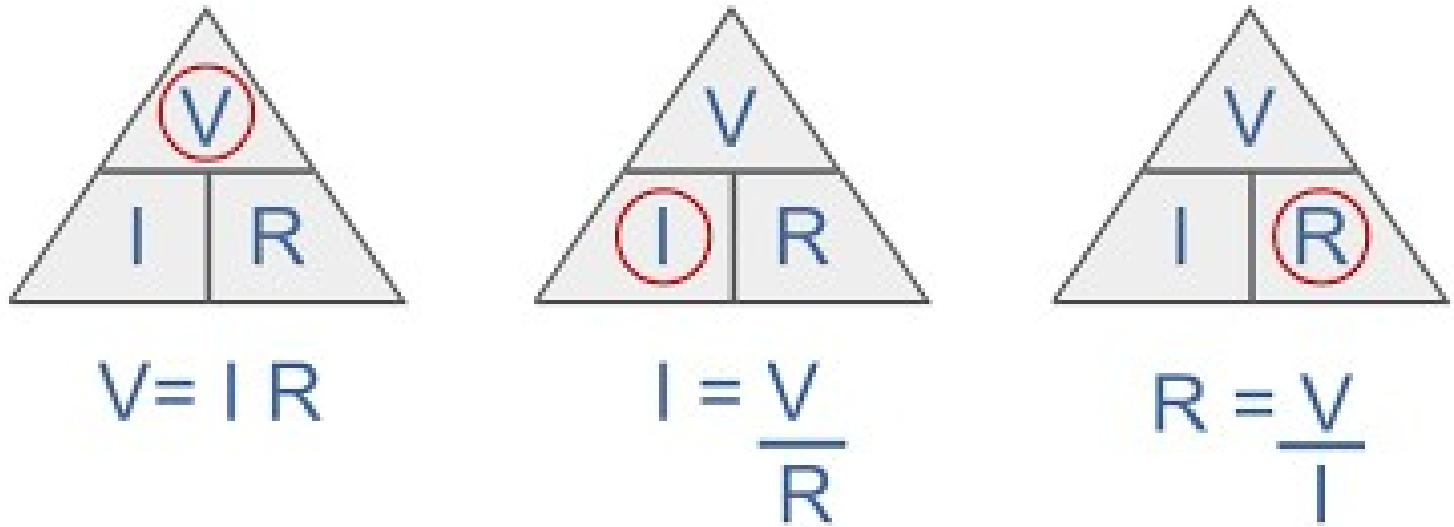






OHM'S LAW

- "The current flowing in a circuit is
  - Directly proportional to the electromotive force (voltage)
  - Inversely proportional to the resistance of a circuit."



OHM'S LAW

- Example: How much current is passing through a resistance of 1,000 ohms when voltage of 1 volt is applied to it?

  I = V /R

  I = 1 volt / 1,000 ohms = 0.001 amps = 1 milliamp (mA)

- Example: How much current is passing through a resistance of 500 ohms when voltage of 10 volts is applied to it?

  I = V /R

  I = 10 volt / 500 ohms = 0.02 amps = 20 milliamps (mA)

OHM'S LAW

- Example: What is the amount of voltage provided by a battery connected with a resistance of 10 ohms if a current of 2 A flows through the circuit?

  V = I x R

  V = 2 A x 10 ohms = 20 volts

- Example: What value of resistance will produce 5 amps of current when connected to a voltage of 25 volts?

  R = V / I

  R = 25 volts / 5 amps = 5 ohms

MULTIPLES /SUB-MULTIPLES OF AN ELECTRICAL UNIT

Prefix	*Symbol*	*Exponential format*	*Multiplier*
tera	**T**	10^{12}	**1 000 000 000 000**
giga	**G**	10^{9}	**1 000 000 000**
mega	**M**	10^{6}	**1 000 000**
kilo	**k**	10^{3}	**1 000**
milli	**m**	10^{-3}	**0.001**
micro	**μ**	10^{-6}	**0.000 001**
nano	**n**	10^{-9}	**0.000 000 001**
pico	**p**	10^{-12}	**0.000 000 000 001**

MULTIPLES /SUB-MULTIPLES OF AN ELECTRICAL UNIT

1K ohm = 1 kilo ohm = 1 x 1000 ohm = 1,000 ohms

20 mA = 20 milliamp = 20 x 0.001 amps = 0.02 amps

2.5 MV = 2.5 mega volts = 2.5 x 1,000,000 volts = 2,500,000 volts = ? kV

3.75 uA = 3.75 micro amps = 3.75 x 0.000001 = 0.00000375 amps = ? mA

5 Gbps = 5 giga bps = 5 x 1,000,000,000 bps = 5,000,000,000 bps = ? Mbps

MULTIPLES /SUB-MULTIPLES OF AN ELECTRICAL UNIT

How many milliwatts are in 3 watts?

Answer: 3,000 mW

What is another way of writing 470 kΩ?

Answer: 470,000 ohms

What is another way of writing 3000 MHz in Giga Hz?

Answer: 3 GHz

MULTIPLES /SUB-MULTIPLES OF AN ELECTRICAL UNIT

- Example: What is the amount of voltage provided by a battery connected with a resistance of 10 kΩ if a current of 2 mA flows through the circuit?

  V = I x R

  V = 2 mA x 10 kΩ = 0.002 amps x 10,000 ohms

  V = 20 volts

- Example: What value of resistance will produce 5 uA of current when connected to a voltage of 15 volts?

  R = V / I = 15 volts / 5 micro amps = 15 / 0.000005

  R = 3,000,000 Ω = 3 MΩ

POWER

- In electricity, it is the rate, per unit time, at which electrical energy is transferred by an electric circuit.
  - Energy can be in the form of heat, light, sound, electromagnetic, etc.
  - Measured in watts (W)
  - Represented by the letter ***P*** in equations
  - A function of both voltage and current, such that

    $P = V \times I$
  - By applying Ohm's Law, we have

    $P = V \times (V / R) = V^2 / R$

    $P = (I \times R) \times I = I^2 \times R$ (Joule's Law)

POWER

- Example: How much power (heat) is dissipated by a resistor when it is connected to a 12-volt battery and 1 amp of current pass through it?

  $P = V \times I = 12 \text{ volts} \times 1 \text{ amp} = 12 \text{ watts}$

- A current of 18 amps flows through a 52-ohm antenna. How much power (in kW) is radiated by the antenna?

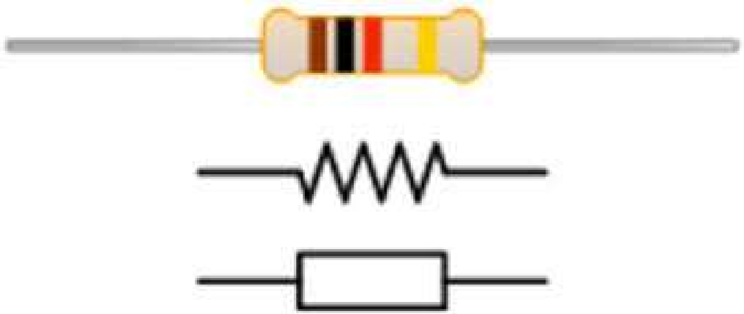
  $P = I^2 \times R = (18 \text{ amps})^2 \times 52 \text{ ohms} = 16{,}848 \text{ watts} = ?\ \text{kW}$

ELECTRONICS

- The study of the flow of electrons through materials and devices.
- Electronic component - any physical entity in an electronic system which affects the flow of electrons.

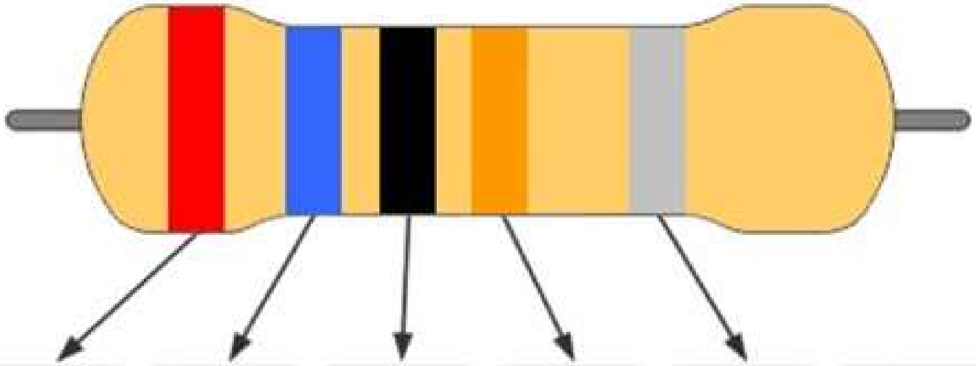
BASIC ELECTRONIC COMPONENTS

- Resistor - a passive two-terminal electrical component primarily used to create and maintain a known safe current within an electrical circuit.
  - Measured in ohms (Ω), represented by ***R*** in equations
  - Can be fixed or variable
  - Types:
    - ***Carbon composition***
    - ***Carbon film***
    - ***Metal oxide film***
    - ***Metal film resistor***
    - ***Wire wound***



BASIC ELECTRONIC COMPONENTS

- Resistor color code



	1st digit	2nd digit	number of zeroes	multiply	tolerance	TCR (ppm/K)
Black	0	0	0	1	1% (F)	100
Brown	1	1	1	10	2% (G)	50
Red	2	2	2	100		15
Orange	3	3	3	1K		25
Yellow	4	4	4	10K		
Green	5	5	5	100K	0.5% (D)	
Blue	6	6	6	1M	0.25% (C)	10
Violet	7	7	7	10M	0.1% (B)	5
Gray	8	8	8	100M	0.05% (A)	
White	9	9	9	1G		
Gold				0.1	5% (J)	
Silver				0.01	10% (K)	
None					20% (M)	

BASIC ELECTRONIC COMPONENTS

- What is the value of the resistor having the color bands as follows: violet – violet – blue - no color ?

  Answer: 77 MΩ

- What is the value of the resistor having the color bands as follows: yellow – violet – orange – no color?

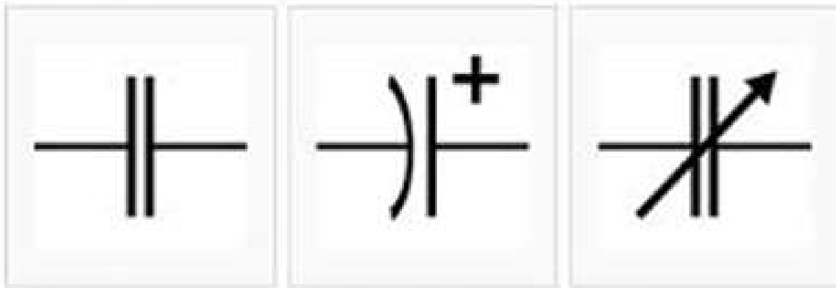
  Answer: 47 kΩ

- What is the value of the resistor having the color bands as follows: green – black – black - silver?

  Answer: 50 Ω (10%)

BASIC ELECTRONIC COMPONENTS

- Capacitor - a passive two-terminal component that stores energy in the form of an electrostatic field.
  - Measured in farads (F), represented by **C** in equations
  - Can be fixed or variable
  - Types:
    - **Electrolytic capacitor**.
    - **Ceramic capacitor**.
    - **Tantalum capacitor**.
    - **Polycarbonate capacitor**
    - **Polyester capacitor**.
    - **Silver mica capacitor**



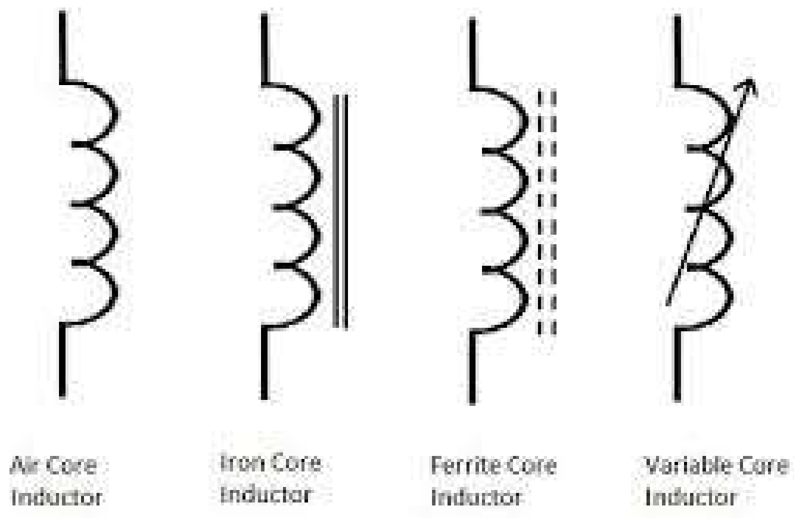
Capacitor

Capacitor, polarized (American)

Capacitor, variable

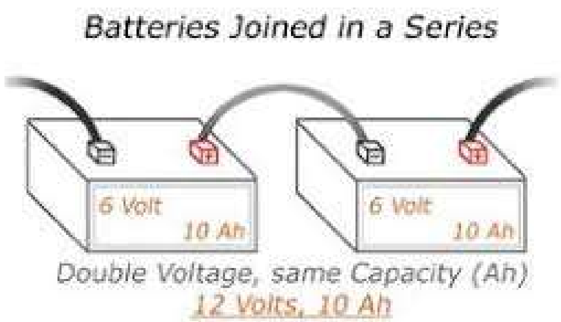
BASIC ELECTRONIC COMPONENTS

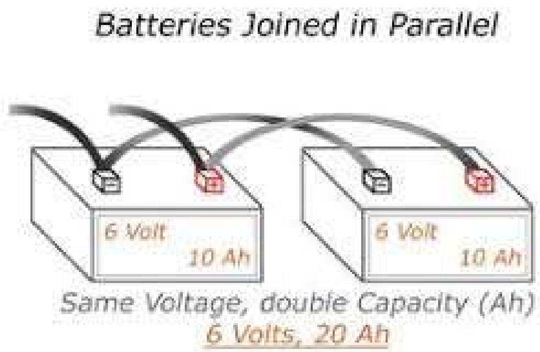
- Inductor - a passive two-terminal component that stores energy in the form of a magnetic field.
  - Measured in henrys (H), represented by ***L*** in equations
  - Can be fixed or variable
  - Types:
    - Air Core Inductor.
    - Iron Core Inductor.
    - Ferrite Core Inductor
    - Iron Powder Inductor.
    - Laminated Core Inductor.
    - Bobbin based inductor.
    - Toroidal Inductor.



BASIC ELECTRONIC COMPONENTS

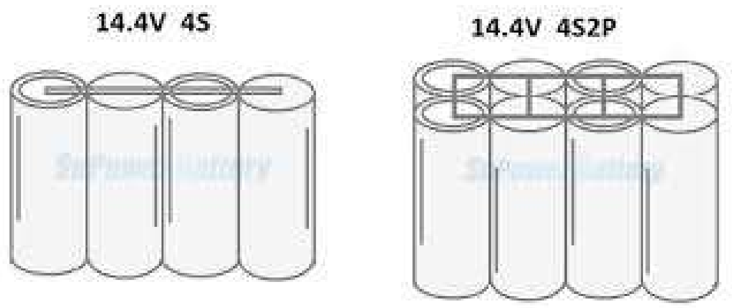
- Battery – a device consisting of one or more electrochemical cells with external connections provided to power electrical devices with DC
  - When connected in series, batteries provide a higher voltage
  - When connected in parallel, batteries provide a higher current capacity (Ah)





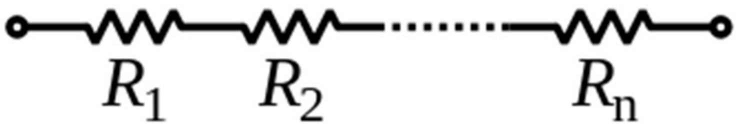
SERIES AND PARALLEL BATTERY CONFIGURATION

Some packs may consist of a combination of series and parallel connections. Laptop batteries commonly have four 3.6V Li-ion cells in series to achieve a nominal voltage 14.4V and two in parallel to boost the capacity from 2,400mAh to 4,800mAh. Such a configuration is called 4s2p, meaning four cells in series and two in parallel. Insulating foil between the cells prevents the conductive metallic skin from causing an electrical short.

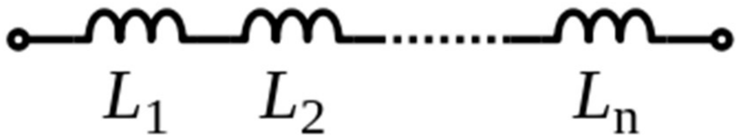


CIRCUIT TYPES

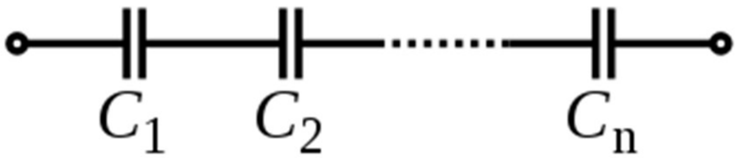
- Series circuit – components are connected one after another so that there is only path for the current, and all the components carry the same amount of current



$$R_{total} = R_1 + R_2 + \cdots + R_n$$



$$L_{total} = L_1 + L_2 + \cdots + L_n$$



$$\frac{1}{C_{total}} = \frac{1}{C_1} + \frac{1}{C_2} + \cdots + \frac{1}{C_n}.$$

SERIES CIRCUIT

- Example: Three resistors R1 = 30 ohms, R2 = 160 ohms and R3 = 40 ohms are connected in series across a generator. What is the total resistance of the circuit?

  Answer: 230 Ω

- Example: What is the total inductance of 3 inductors connected in series, with the following values: 3mH, 5 mH and 22 mH?

  Answer: 30 mH

- Example: What is the total capacitance of 3 capacitors connected in series, with the following values: 6 pF, 6 pF and 12 pF?

  Answer: 2.4 pF

SERIES CIRCUIT

- For series circuits, remember:
  - The total current of the circuit is the same as the current through each component

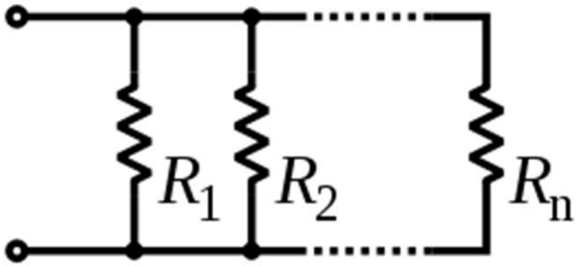
    ($I_{TOTAL} = I_1 = I_2 = ... = I_N$)

  - The total voltage of the circuit is equal to the sum of the voltages on each component

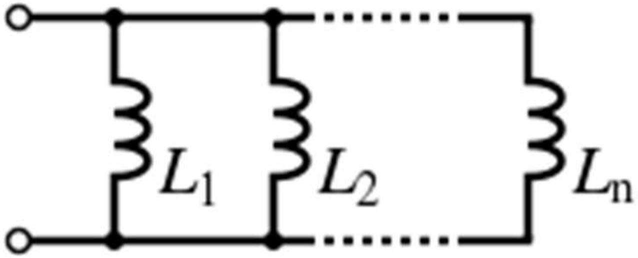
    $V_{TOTAL} = V_1 + V_2 + ... + V_N$

CIRCUIT TYPES

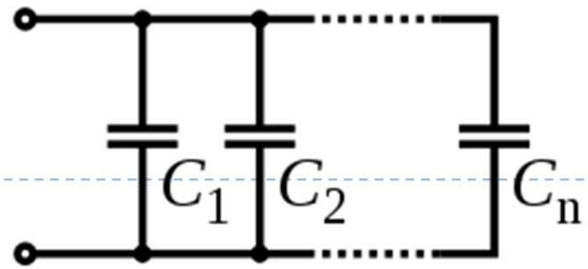
- Parallel circuit – components are connected in parallel to one another so that all the components have the same amount of voltage across them



$$\frac{1}{R_{\text{total}}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_n}.$$



$$\frac{1}{L_{\text{total}}} = \frac{1}{L_1} + \frac{1}{L_2} + \cdots + \frac{1}{L_n}.$$



$$C_{\text{total}} = C_1 + C_2 + \cdots + C_n.$$

PARALLEL CIRCUIT

- Example: Three resistors R1 = 10 KΩ, R2 = 15 KΩ and R3 = 30 KΩ are connected in parallel across a generator. What is the total resistance of the circuit?

  Answer: 5 KΩ

- Example: What is the total inductance of 3 inductors connected in parallel, if each inductor has a value of 30mH?

  Answer: 10 mH

- Example: What is the total capacitance of 3 capacitors connected in parallel, with the following values: 6 pF, 6 pF and 12 pF?

  Answer: 24 pF

PARALLEL CIRCUIT

- For parallel circuits, remember:
  - The total voltage of the circuit is the same as the voltage across each component

    ($V_{TOTAL} = V_1 = V_2 = ... = V_N$)

  - The total current of the circuit is equal to the sum of the currents on each component

    $I_{TOTAL} = I_1 + I_2 + ... + I_N$

HOW COMPONENTS REACT TO AC

Component	DC (f = 0)	AC (f > 0)
Resistor	Limits current	Limits current
Capacitor	Open circuit	Resistance decrease as f increases
Inductor	Short circuit	Resistance increase as f increases

*Capacitors store electrostatic field.
*Inductors store magnetic field.

REACTANCE

- Reactance – the opposition to current due to storage of energy
  - Measured in ohms (Ω), represented by ***X*** in equations

- Inductive reactance, $X_L = 2\pi f L$

where f = frequency in hertz
L = inductance in henrys

- Capacitive reactance, $X_C = 1 / (2\pi f C)$

where f = frequency in hertz
C = capacitance in farads

REACTANCE

- Example: A coil of inductance 150mH and zero resistance is connected across a 100V, 50Hz supply. Calculate the inductive reactance of the coil and the current flowing through it.

F = 50 Hz L = 150 mH = 0.150 H V = 100 V

$X_L = 2\pi f L = 2 \times 3.14 \times 50 \text{ Hz} \times 0.150 \text{ H} = \mathbf{47.1\ \Omega}$

$I = V / R = 100 \text{ V} / 47.1\ \Omega = \mathbf{2.12\ A}$

REACTANCE

- Example: Find the current flowing in a circuit when a 4 μF capacitor is connected across a 220v, 60Hz supply.

F = 60 Hz C= 4 μF = 0.000004 F V = 220 V

X_C = 1 / (2π f C) = 1 / (2 x 3.14 x 60 Hz x 0.000004 F) = **663.5** Ω

I = V / R = 220 V / 663.5 Ω = **0.332 A, or 332 mA**

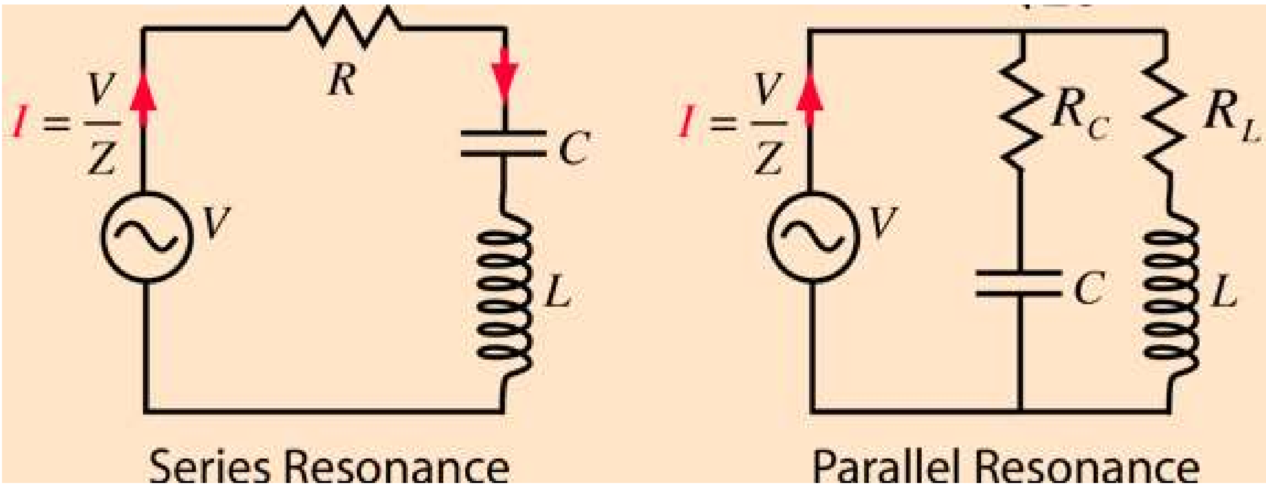
IMPEDANCE

- Impedance – the effective resistance of an electric circuit or component to AC, arising from the combined effects of ohmic resistance and reactance
  - Measured in ohms (Ω), represented by ***Z*** in equations

$$Z = R + jX = R + j(X_L - X_C)$$

RESONANCE

- Resonance – the condition that exists when the inductive reactance and the capacitive reactance are of equal magnitude, causing electrical energy to oscillate between the magnetic field of the inductor and the electric field of the capacitor.

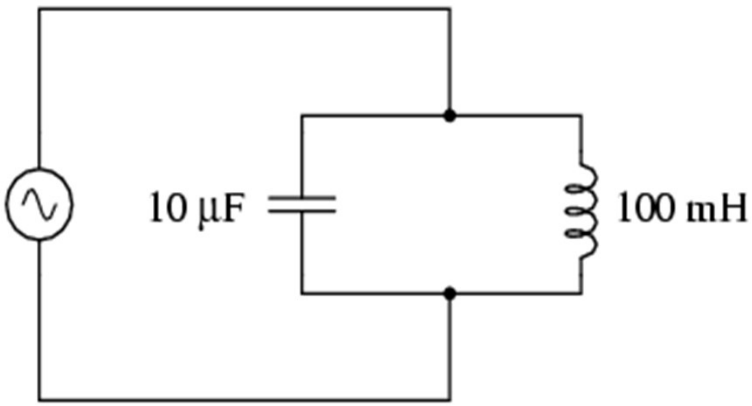


RESONANCE

- During resonance, $X_L = X_C$

$$f = \frac{1}{2\pi\sqrt{LC}}$$

- Example: Find the resonant frequency of the following circuit:



$$f = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{(2)(3.14)\sqrt{(.1H)(.00001F)}}$$

$$\Rightarrow f = \frac{1}{(6.28)\sqrt{.000001}} = \frac{1}{(6.28)(.001)}$$

$$\Rightarrow f = 159.24Hz$$

QUESTIONS?