

Electrical Power System Fundamentals
for Non-Electrical Engineers

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Technology Training that Works

Presents

Electrical Power System Fundamentals for Non-Electrical Engineers

Revision 1

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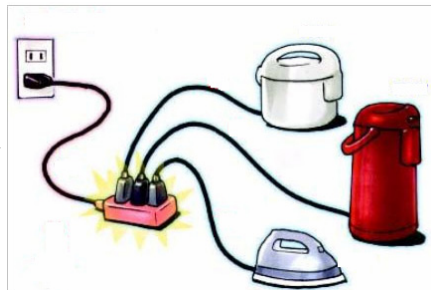
1. Overview of electrical power systems



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What is Electricity?

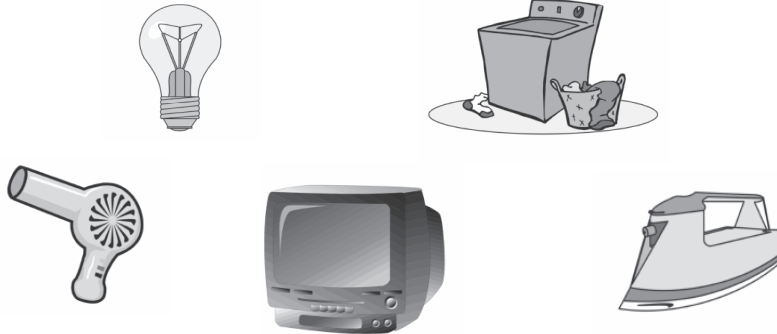
- Most widely used and an extremely versatile form of energy.



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What is Electricity? (contd...)

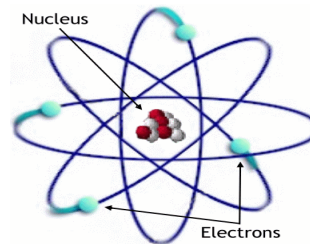
- Flow of **current** that is used to power lights, motors, tools, and many other devices.



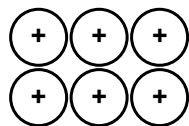
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Charge

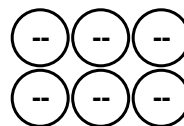
- Charge is of two types
 - Positive charge
 - Negative charge
- Charge is carried by very tiny particles called **ELECTRONS** and **PROTONS**.



PROTONS



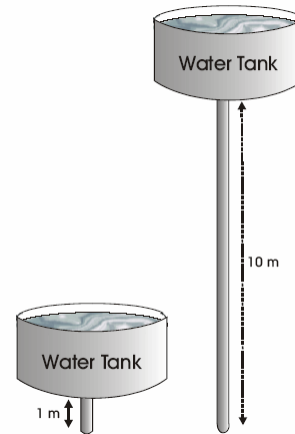
ELECTRONS



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How are charges moved?

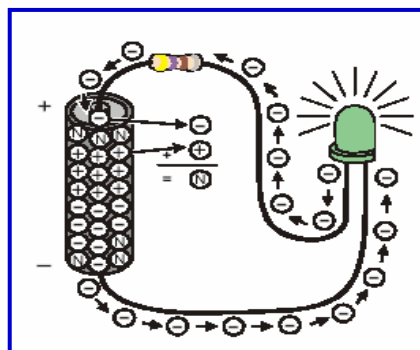
- An amount of energy is needed to move.
- **POTENTIAL DIFFERENCE** or **VOLTAGE** is that energy or electric force which causes charges to move.
- 10 Volts sends more current than 1 Volt.



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Charges moving in a circuit

- Voltage from energy source causes current



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Question

What are negatively charged particles?

- A) Protons
- B) Electrons
- C) Neutrons



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Lightning

- **Electricity** occurs in nature in the form of lightning and static electricity.



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Lightning

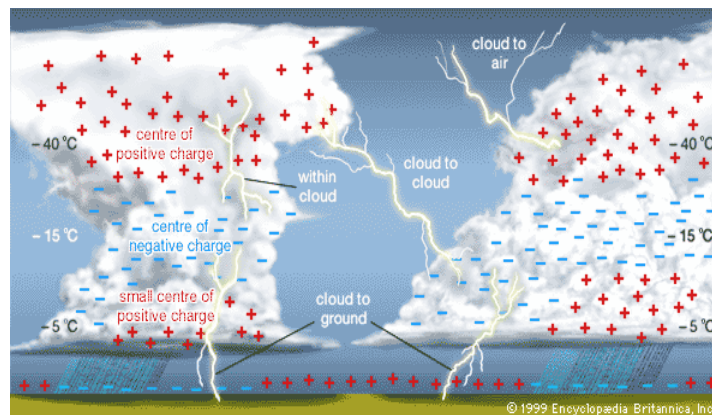
- Lightning is one of the most dramatic examples of electrical discharge.
- May Occur
 - Between cells in the same storm (inter cloud lightning)
 - Within a cloud (intra cloud lightning)
 - Cloud to air
 - Cloud to ground (CG)



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Lighting (contd...)

- Lightning is an electrical discharge in the atmosphere, very similar to a spark.

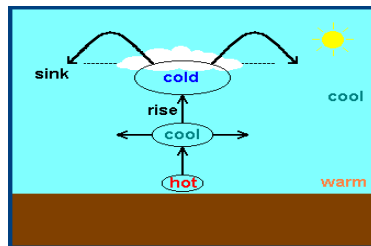


Source : Encyclopædia Britannica

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Lightning occurs.....

- Clouds form when air near the earth's surface is warmed, causing it to rise.
- As the air rises it loses its heat and cools.
- When air cool, it condenses
- When condensation occurs, clouds take shape.



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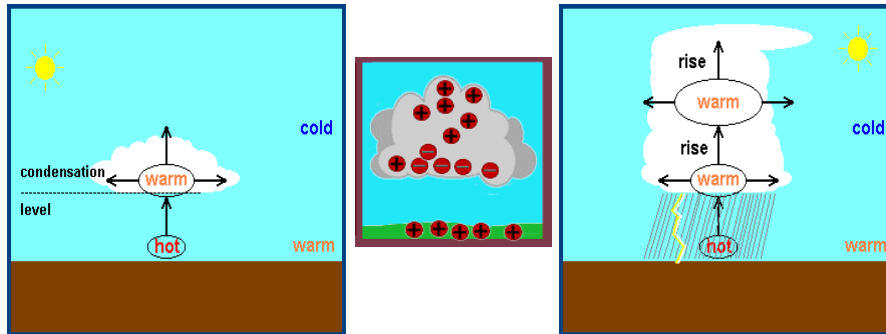
Lightning (contd...)

- Thunderstorms occur in a cloud called a cumulonimbus cloud.
- Within this cloud, there are many electrons giving off their charges.
- Positive charges gather toward the upper portion and negative charges in the bottom of the cloud
- Due to the difference between positive and negative charges lightning discharge occurs.



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Lightning phenomenon.....



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Quiz Question

Lightning is a discharge of....

- A) Protons
- B) Neutrons
- C) Electrons
- D) None



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Static electricity

- We notice static electricity usually in the winter when the air is very dry
- During summer, the air is more humid
- The water in the air helps electrons move off you more quickly, so you can not build up as big a charge.



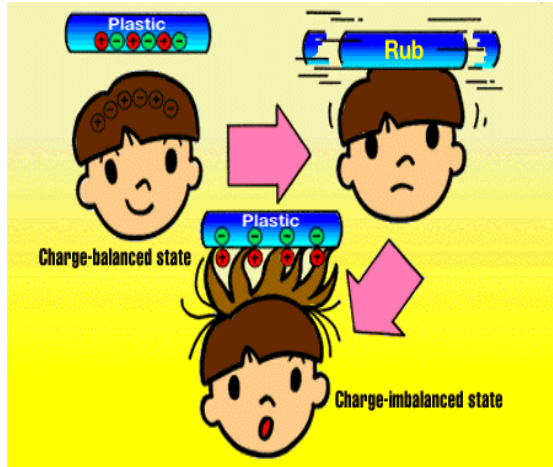
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When you touch a door knob...



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Examples of static electricity



Technology Training that Works

Examples of static electricity



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Limitations of static electricity

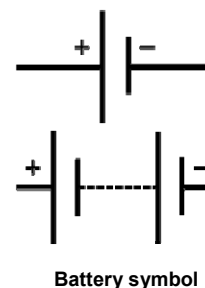
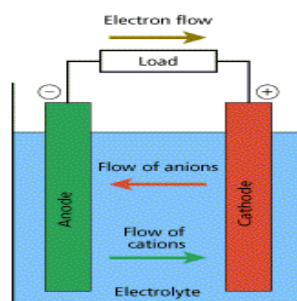
- In thunderstorm clouds, the static charges can build up to millions of volts, which is very dangerous
- It cannot move and is limited to only small distance
- Static electricity can cause damage to electronic equipment
- Can also cause uncomfortable shocks
- Can be responsible for the ignition of flammable gases, such as the vapors produced by petrol (gasoline) when you are filling your car.



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Battery

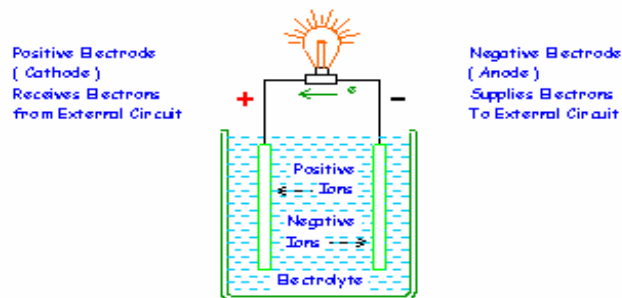
- Device that converts chemical energy into electrical energy.
- The first battery was created by Alessandro Volta in 1800.



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Battery (contd...)

- A Battery consists of three components:
 - positive electrode
 - negative electrode and
 - an electrolyte



www.grc.nasa.gov/WWW/Electrochemistry/images/batt2.gif

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Quiz Questions

1. What is an anode?

- A) Positive terminal
- B) Negative terminal
- C) neutral

2. What is a cathode?

- A) Positive terminal
- B) Negative terminal
- C) neutral



Technology Training that Works

Battery (contd...)

- A battery is essentially a can full of chemicals that produce electrons through chemical reactions.
- Chemical reactions that produce electrons are called **electrochemical reactions**.
- Watches, calculators and cars all use batteries.
- The most familiar are single-use alkaline batteries.



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Battery (contd...)

- Batteries are usually divided into two broad classes:
 - Primary batteries
 - Secondary batteries



Primary batteries

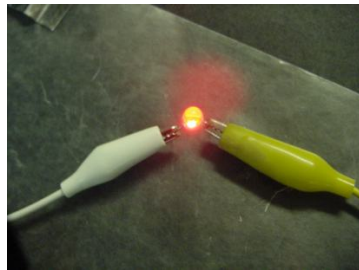
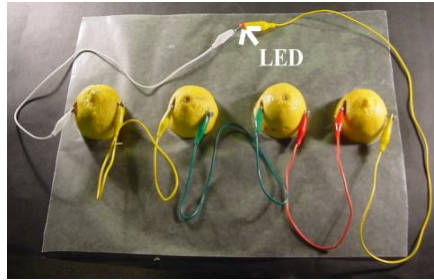
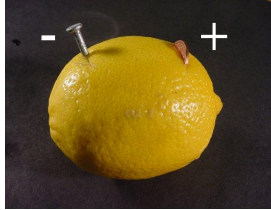


Re-chargeable batteries



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Battery (contd...)



www.hilaroad.com/camp/projects/lemon/lemmon_battery.html

Technology Training that Works

Quiz Question

Are car batteries re-chargeable?



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Quiz Question

Batteries used in watches, toys etc....

What kind of batteries are they?

A) Primary B) Secondary

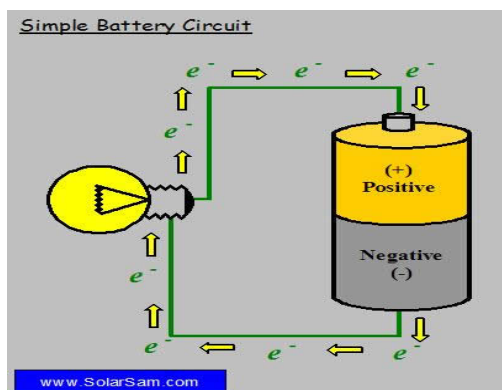
C) Rechargeable



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How does electricity flow?

- A battery connected by conductors (copper wire) to electrical components (bulb).

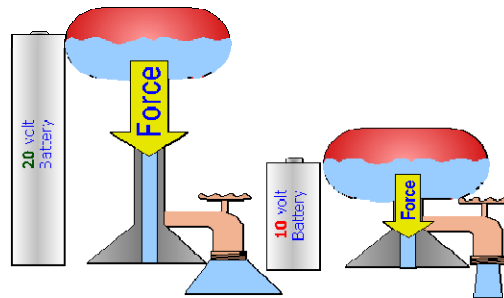


www.bcae1.com/current.htm

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Voltage

- Voltage is the electrical force, or "pressure", that causes current to flow in a circuit
- It is measured in VOLTS (V or E).

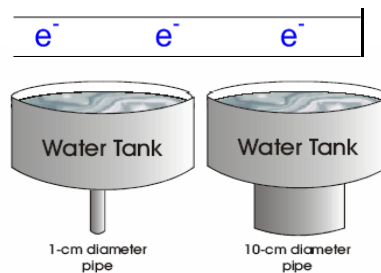


www.bcae1.com/current.htm

Technology Training that Works

Electric current

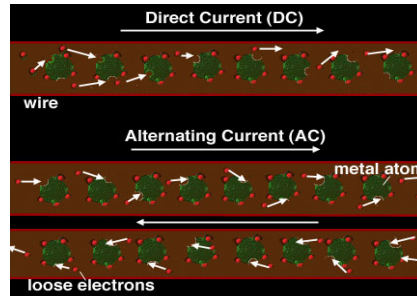
- Current is the movement of electrical charge - the flow of electrons through the electronic circuit.
- Current is measured in AMPERES (AMPS, A or I).



Technology Training that Works

Direct current (DC) & Alternating current (AC)

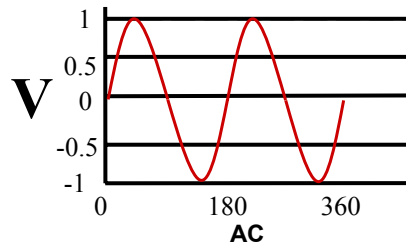
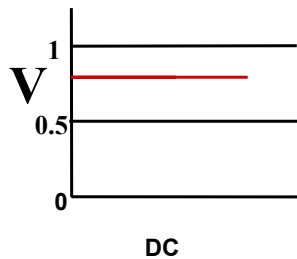
- Flow of current can be DIRECT Current (DC) or ALTERNATING Current (AC)



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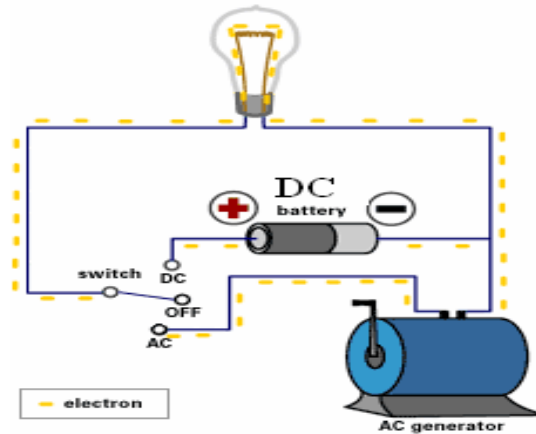
DC & AC currents

- Direct current is a continuous current (I) per unit time
- Alternating current (I) is sinusoidal function of time.



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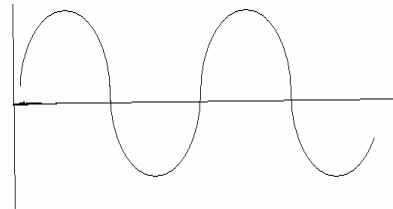
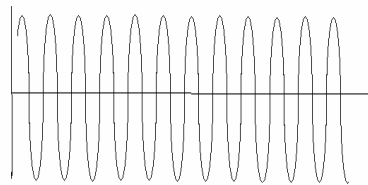
Direct vs Alternating current



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Frequency

- Measurement of the number of occurrences of a repeated event per unit of time.
- Measure the time between two consecutive occurrences of the event (the Time period T)



Technology Training that Works

Frequency

- Compute frequency as

$$f=1/T$$

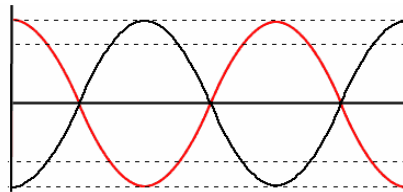
- SI Units is measured in hertz (Hz) named after the German physicist Heinrich Hertz.
- Frequency was originally called cycles per second (cps), a term which is still sometimes used.



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Single phase AC

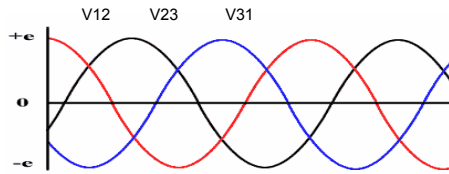
- A single-phase system is one where there is only one AC voltage source (one source voltage waveform).
- Single-phase distribution is used when loads are mostly lighting and heating, with few large electric motors.



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Three Phase AC

- The generation of AC electric power is commonly three phase.
- In Three phase AC, the waveforms of three supply conductors are offset from one another by 120° .
- Standard frequency is 60 Hz.



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Quiz Question

What is the nature of power supply we get at our home?

- A) AC**
- B) DC**
- C) Both**



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Electric power

- Defined as the amount of work done by an electric current per unit time.
- The unit of power is the WATT
- For a resistor in a DC Circuit the power is given by the product of applied voltage and the electric current

$$\text{Power (P)} = \text{Voltage (V)} \times \text{Current (I)}$$



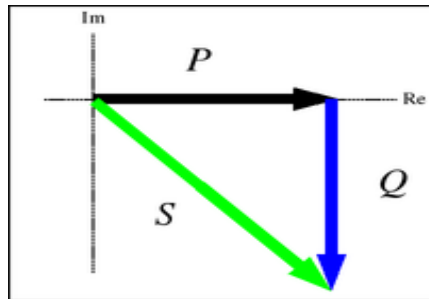
AC power

- AC power flow has the three components:
 - Real power (P)
 - It is in phase with the applied voltage (V)
 - Also known as the active component.
 - Measured in watts (W)
 - Reactive power (Q)
 - It is not in phase with the applied voltage (V)
 - Also known as Idle or wattless power
 - Measured in reactive volt-amperes (VAr)



Power factor (contd...)

- Apparent power (S)
 - It is the vector sum of real and reactive power
 - Measured in volt-amperes (VA)



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Power factor

- It is the ratio of the real power to the apparent power.
- Always apparent power should be equal or more than the real power
- An ideal power factor is unity or 1.



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Power factor (Contd...)

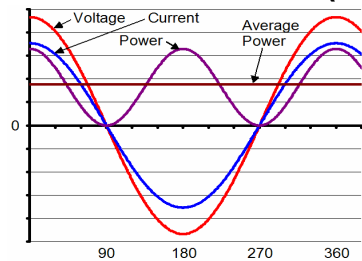


Fig.1

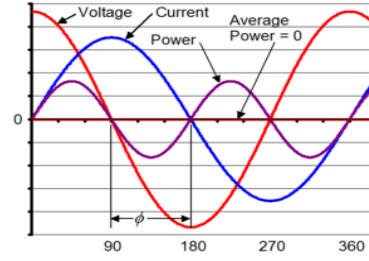


Fig.2

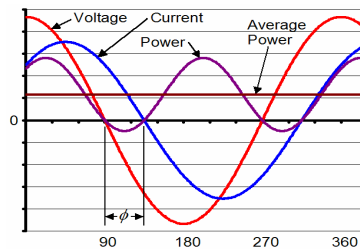


Fig.3



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Power factor (contd...)

- Low-power-factor loads increase losses in a power distribution system
- And result in increased energy costs.



Technology Training that Works

Quiz Question

How do you measure Power?

- A) Volts
- B) Amps
- C) Watts



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Power factor correction (PFC)

- It is a technique of counteracting the undesirable effects of electric loads that create a power factor that is less than 1.
- It may be applied either by an electrical power transmission utility to improve the stability and efficiency
- Or may be installed by individual electrical customers
- To reduce the costs charged to them by their electricity supplier.



Technology Training that Works

Types of PFC Techniques

- Passive PFC
 - This is a simple way of correcting the nonlinearity of a load by using capacitor banks.
 - It is not as effective as active PFC.
 - Switching the capacitors into or out of the circuit causes harmonics,
 - Active PFC or a synchronous motor is preferred.



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PFC Techniques (contd...)

- Active PFC
 - It is a power electronic system that controls the amount of reactive power drawn by a load
 - Obtains a power factor as close as possible to unity.
 - The active PFC controls the input current of the load
 - Active PFC is the most effective and can produce a PFC of 0.99.



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PFC Techniques (contd...)

- Synchronous PFC
 - Synchronous motors are used for PFC
 - In past motors without loads were used
 - Motors ran free at capacitive (leading) power factor for the purposes of PFC.



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Electric energy or electric work

- **Energy** is the capacity for doing work
- **Electrical energy** is usually measured in watt-hours.
- Electric work is said to be done when an electric charge flows through a conductor.
- The SI unit of electrical energy is the **joule**.



Technology Training that Works

Relation between Power & Energy

- Power is the rate at which electrical energy is transmitted
- Power is energy per unit time.

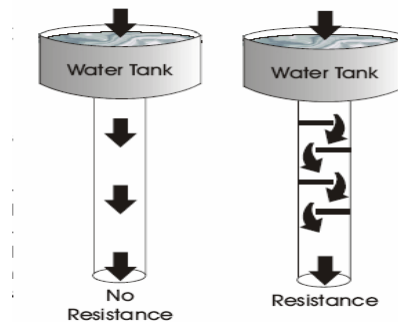
$$\text{Power} = \frac{\text{work (or energy)}}{\text{Time in seconds}}$$



Technology Training that Works

Resistance

- Resistance is a property that slows the flow of electrons — the current.
- Resistance causes an opposition to the flow of electricity in a circuit. It is measured in OHMS (Ω).



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Resistance (contd..)

- Resistance to flow increases with decreasing size of pipe/conductor
- Resistance creates losses/Heat
- Losses proportional to square of current
- Doubling voltage halves current, reduces losses to one quarter when power is constant.



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Pressure Drop

- Loss incurred overcoming resistance reduces pressure
- Same effect water and electricity
- Equipment requires a minimum pressure to work efficiently
- Pressure/voltage drop must be controlled



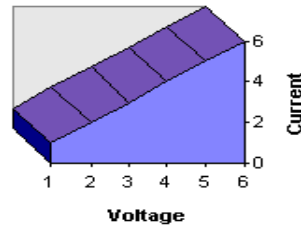
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Relation between V, R & I

- Ohm's Law is a mathematical equation explaining the relationship of voltage (V), current (I), and resistance (R)
- It is defined as:

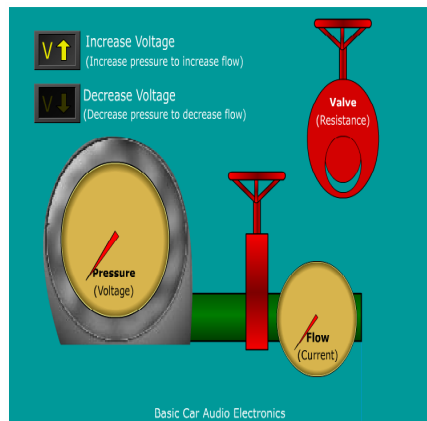
$$V = I \times R$$
$$I = \frac{V}{R} \quad \text{or} \quad R = \frac{V}{I}$$

Increase in Voltage
(Constant Resistance)

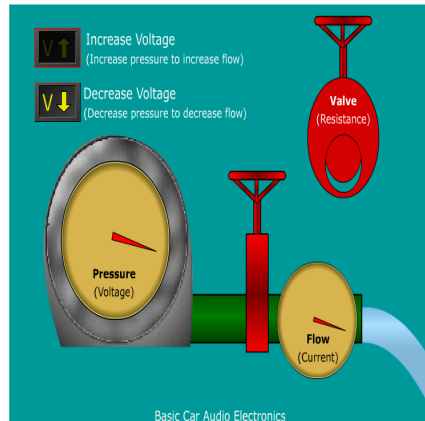


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Ohm's law



Picture.1



Picture.2



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Analogues

Electrical name	Hydraulic Equivalent
-----------------	----------------------

- | | |
|------------------|---------------|
| ➤ VOLT----- | PASCAL |
| ➤ COULOMB----- | LITRE |
| ➤ AMPERE----- | LITRE/SEC. |
| ➤ OHM----- | RES. TO FLOW |
| ➤ VOLT DROP----- | PRESSURE DROP |



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Quiz Question

How do you measure resistance?

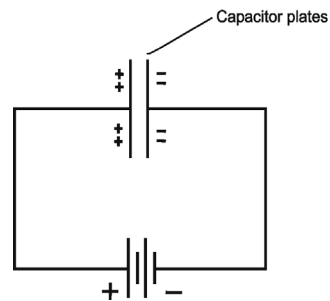
- A) Volts**
- B) Ohms**
- C) Amps**



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Capacitance

- An object that stores charge is called a capacitor
- Consists of two metal plates separated by an insulator
- Capacitance =
- Charge Q / Potential difference V



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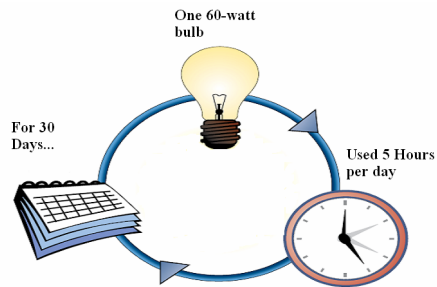
Why is electrical energy a preferred form of energy?



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Electricity Importance

- It's hard to imagine what life would be like without ELECTRICITY.



contd.....



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Electricity Importance (contd...)

- The fact is that electricity can be used in a thousand different ways. For example:
 - Electric motors turn electricity into motion.
 - Light bulbs, fluorescent lamps and LEDs turn electricity into light.
 - Computers turn electricity into information.
 - Telephones turn electricity into communication.
 - TVs turn electricity into moving pictures.



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Electricity Importance (contd...)

- Speakers turn electricity into sound waves.
- Stun guns turn electricity into pain.
- Toasters, hair dryers and space heaters turn electricity into heat.
- Radios turn electricity into electromagnetic waves that can travel millions of miles.
- X-ray machines turn electricity into X-rays.



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It is hard to imagine modern people living without electricity.



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Any questions ?



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