Electricity Basics

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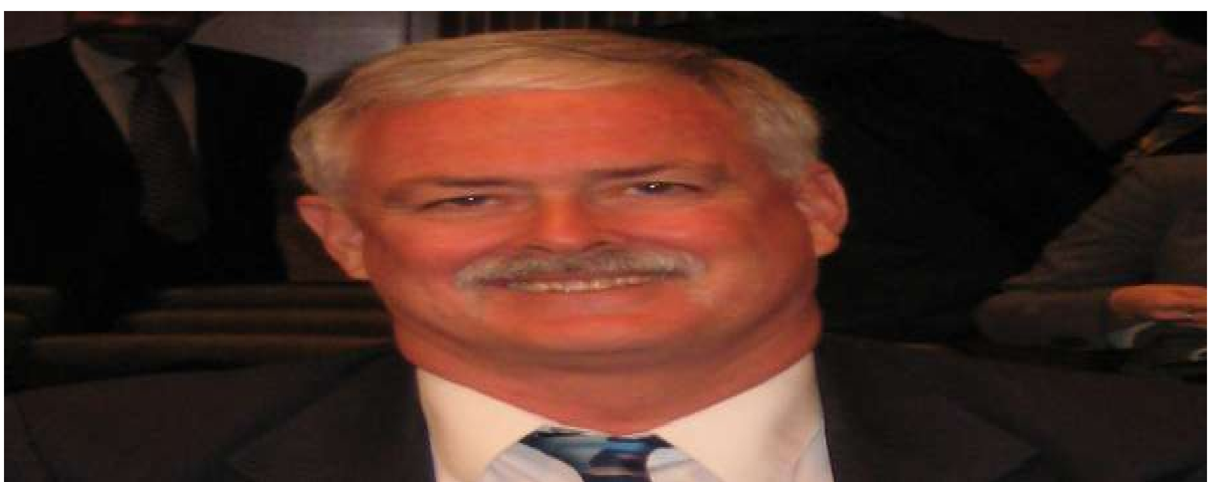
Dr. House has a Bachelors, two Masters, and a Ph.D. in Engineering and Economics from University of California at Davis. He is a Certified Energy Manager (CEM) and a Certified Sustainable Development Professional (CSDP) with the Association of Energy Engineers. He taught engineering in Graduate School at U.C. Davis for a number of years and is the founder and Co-Director of Hydropower for the U.C Davis Energy Institute. He worked for the California Energy Commission for five years as a utility planner, and he was the chief utility planner for the California Public Utilities Commission for five years. In 1990 he went out into the consulting business, starting his own business (Water and Energy Consulting). He has been the Association of California Water Agencies (ACWA) energy consultant since 1992, representing 500 water agencies which are responsible for over 90 percent of the water delivered in California, and is the California Rural Water Association (CRWA) energy specialist, representing over 1,100 rural water and wastewater systems. Dr. House also works for the California Public Utilities Commission as an expert witness on transmission issues and is their water-energy expert, and for the California Energy Commission as a researcher. He is an investment management expert consultant in the water and energy areas for: Gerson Lehrman Group-GLG Scholar Program, eWork Markets, Price Waterhouse-Vantage Marketplace, Roundtable Group, and Standard & Poor's–Society of Industrial Leaders. He has been responsible for training and installation of over 25 small hydroelectric facilities in Southeast Asia. He is a member of the American Water Works Association (AWWA), American Society of Civil Engineers (ASCE), Sigma Xi- the National Research Honor Society, and Association of Energy Engineers (AEE).



Electricity Basics Outline

- Introduction
- Safety
  - Electrical hazards, safety equipment, electrocution, fire, arc flash, power lines
- Electricity Characteristics
  - volt, watt, amp, coulomb, ohm, electric laws
- Production of Electricity
  - Electromagnetic spectrum, natural, DC, AC, AC generation
- Conduction of Electricity
  - conductor and insulators, inductance and capacitance, reactance and impedance, electricity circuits, fuses, relays, transformers
- Troubleshooting
  - Electricity tools/instruments, voltage drop/resistance, harness/switches, relays, modules/controllers
- Electrical Issues
  - Power factor, harmonics, corrections
- Energy Efficiency
- Final Review
  - How to read a nameplate

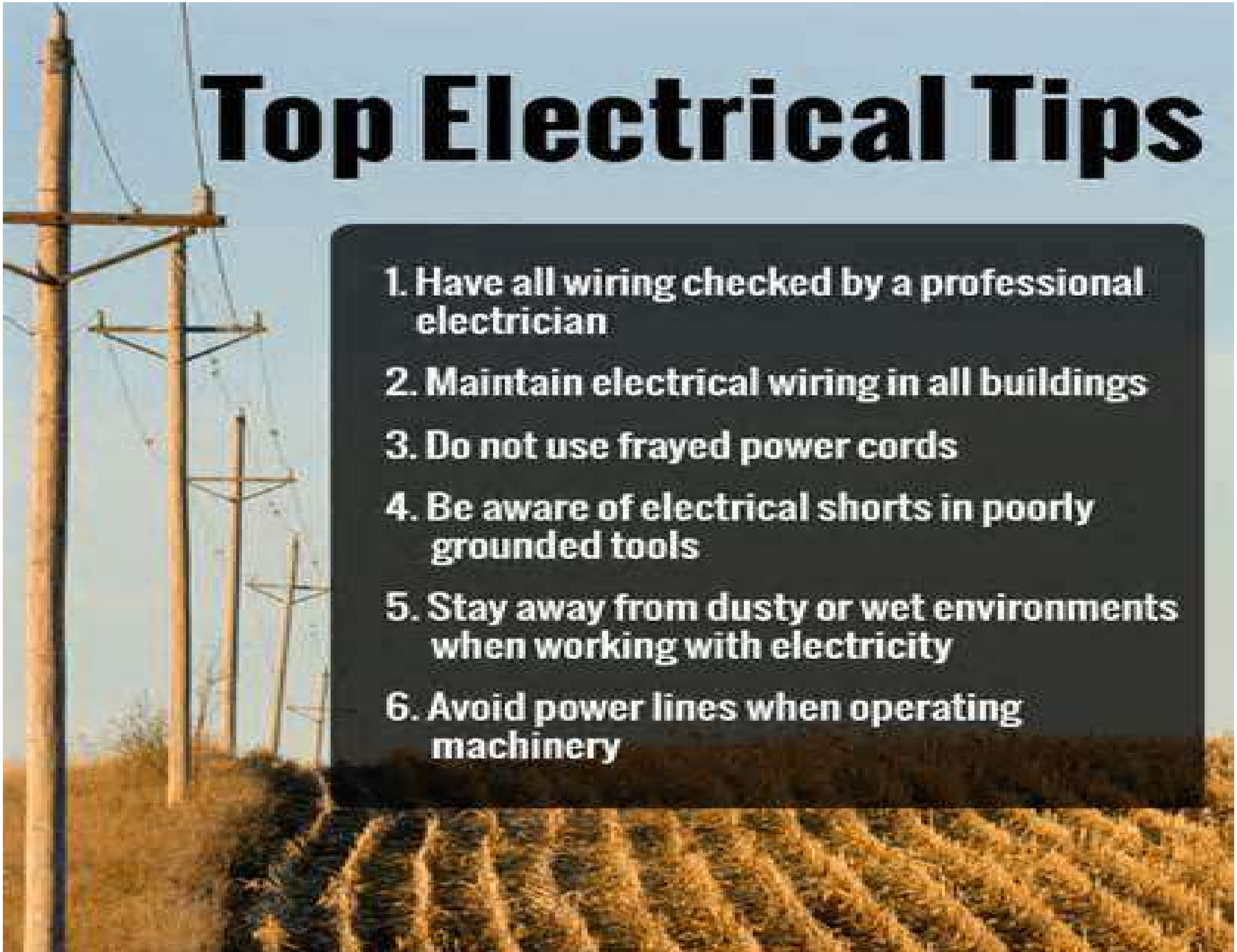
Effects of Current on the Body

Men

- Perception Threshold
  - 0.0001 Amps (1 mA)
- Painful Shock
  - 0.009 Amps (9 mA)
- Cannot Let-Go Level
  - 0.010 Amps (10 mA)
- Ventricular Fibrillation
  - 0.100 Amps (100 mA) for 3 seconds
  - 0.200 Amps (200 mA) for 1 second
- Heart Failure
  - 0.5 Amps (500 mA)
- Organ Burn and Cell Breakdown
  - 1.5 Amps (1500 mA)

Women

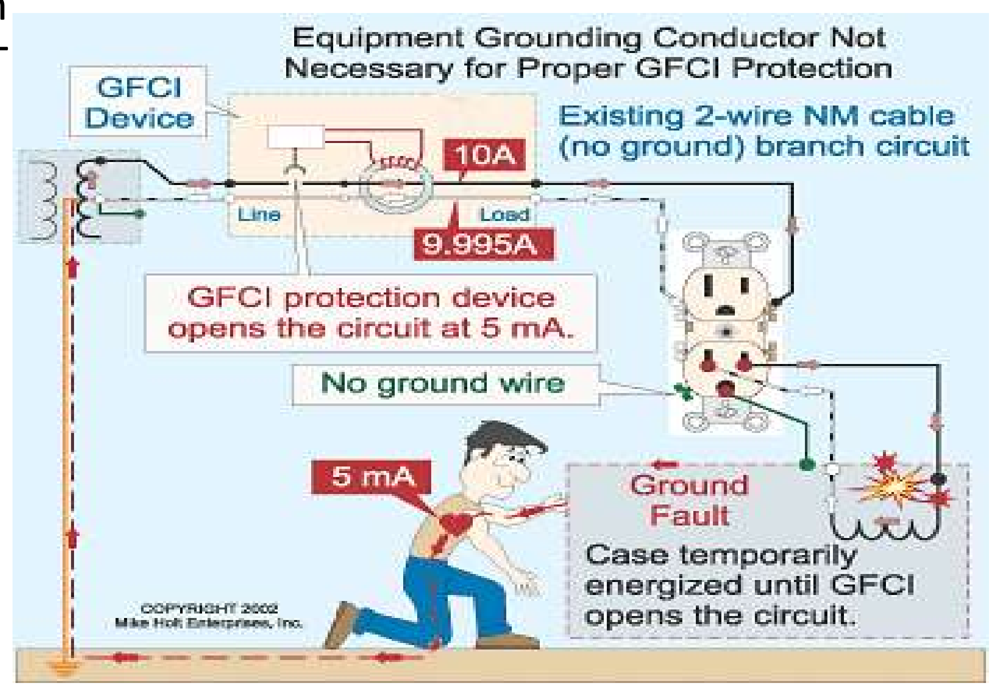
- Perception Threshold
  - 0.0007 Amps (0.7 mA)
- Painful Shock
  - 0.006 Amps (6 mA)
- Cannot Let-Go Level
  - 0.010 Amps (10 mA)
- Ventricular Fibrillation
  - 0.100 Amps (100 mA) for 3 seconds
  - 0.200 Amps (200 mA) for 1 second
- Heart Failure
  - 0.5 Amps
- Organ Burn and Cell Breakdown
  - 1.5 Amps (1500 mA)


Top Electrical Tips
1. Have all wiring checked by a professional electrician
2. Maintain electrical wiring in all buildings
3. Do not use frayed power cords
4. Be aware of electrical shorts in poorly grounded tools
5. Stay away from dusty or wet environments when working with electricity
6. Avoid power lines when operating machinery

Your Best Friends

1) Never work on a closed circuit. **LOCKOUT**. Only person placing lockout allowed to remove it. ALWAYS CHECK TO SEE IF LOCATION IS HOT.

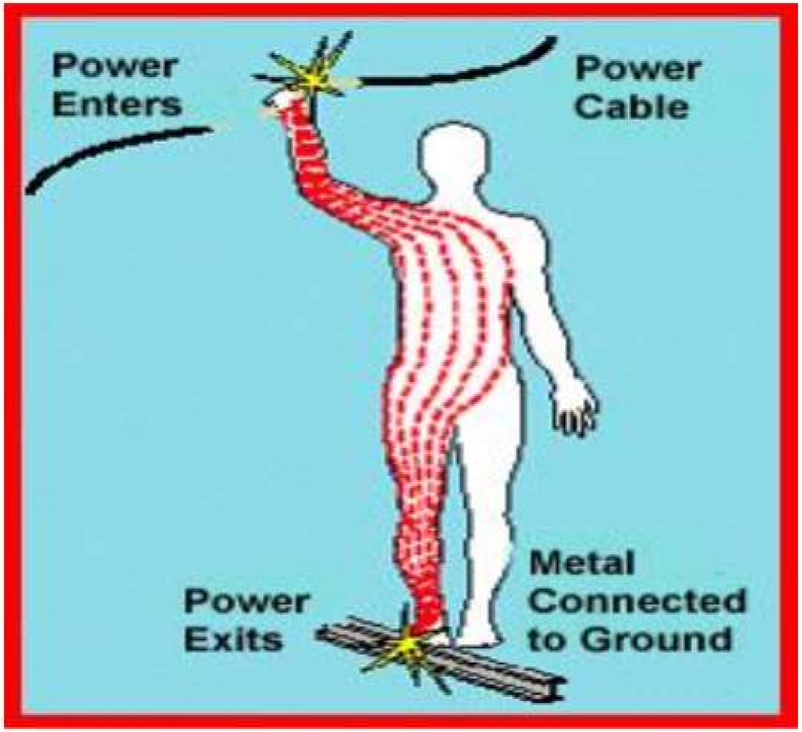
2) **GFCIs** monitor hot and neutral. Open circuit if difference > 5mA. ALWAYS TEST BEFORE USE.



Basic Safety

Electrical Hazards

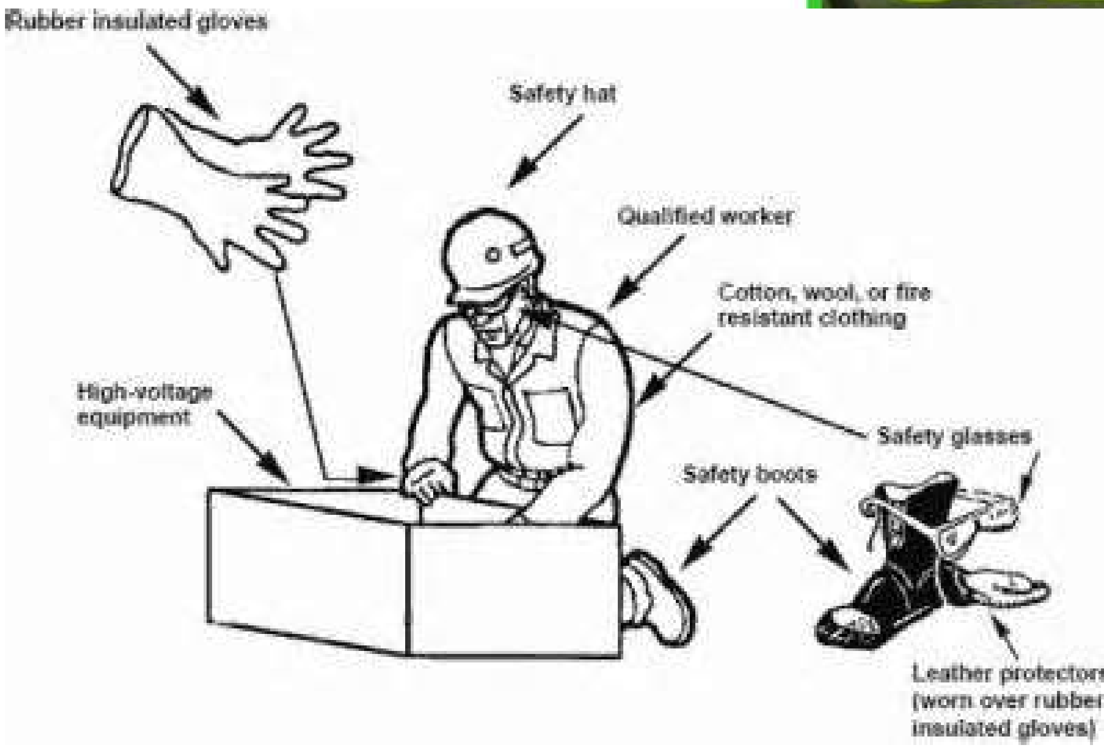
- Improper grounding
- Exposed electrical parts
- Inadequate wiring
- Overhead power lines
- Damaged insulation
- Overloaded circuits
- Wet conditions
- Dusty conditions
- Damaged tools and equipment
- Accidents, Careless, and Stupidity



- Always consider these safety precautions:
  - Personal protective equipment (PPE),
  - Inspect tools,
  - Ground fault circuit interrupters (GFCIs),
  - Lock-out/tag-out.

PPE - Personal Protection Equipment

- PPE for electrical hazards include:
  - hardhats
  - rubber or insulating gloves
  - insulating clothing



Gloves are Important

- Use appropriate rubber insulating gloves.
- Make sure the gloves fit properly.
- Make sure the glove rating matches with the work to be performed.
- Not all gloves can be used to prevent electric shock.

Electrical burn on hand and arm.

Safety

- Check the meter first!
- Check the circuit, always to ground!!
- LOCK OUT!
- Check the circuit and meter again!
- Have Dave grab that wire
- Call a licensed electrician

RCAC.org

ARC Flashes

An electric arc or an arcing fault is a flashover of electric current through air in electrical equipment from one exposed live conductor to another or to ground.

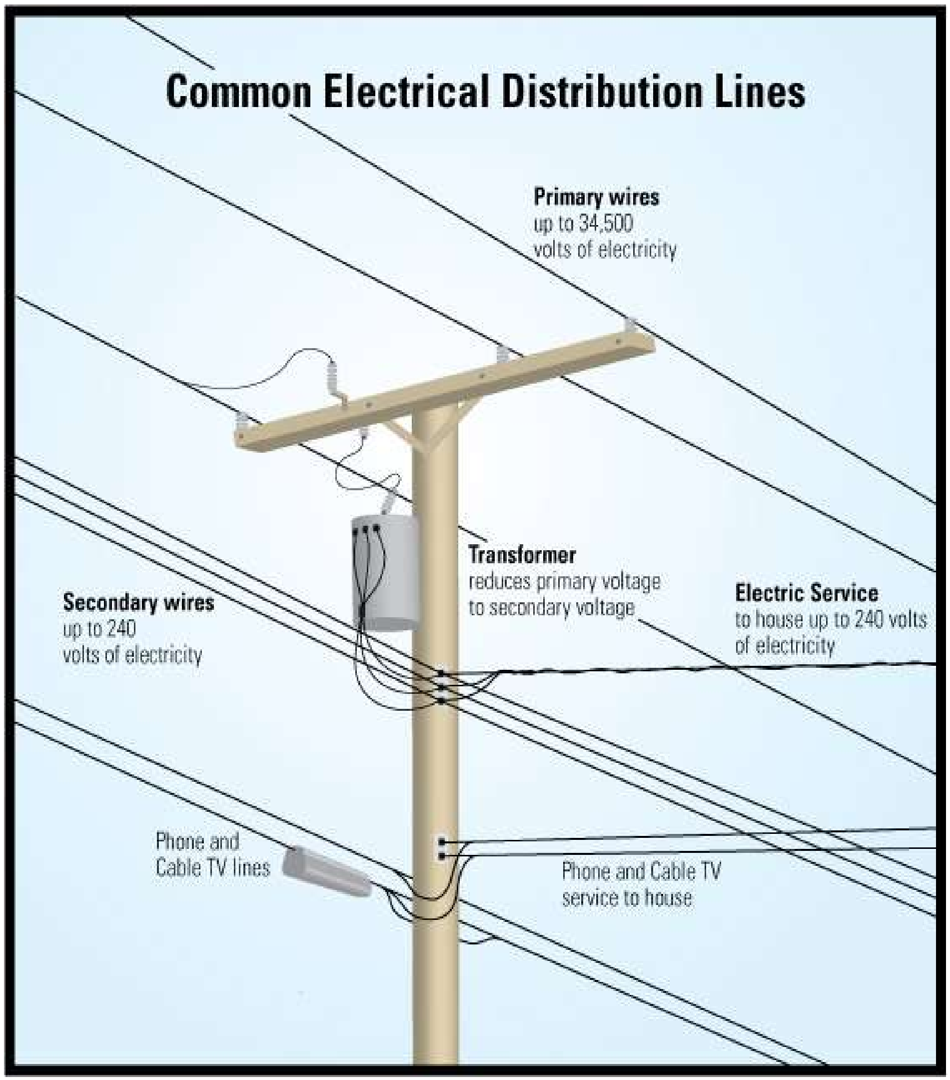
Human error – unsafe work procedures, maintenance mistakes, and mishandling tools, wires, and metal covers;

Negligent preventive maintenance – not checking for loose termination, allowing dust and debris build-up (critical in medium voltages and higher), and not testing stored energy (e.g., spring-operated bolted pressure switches); and

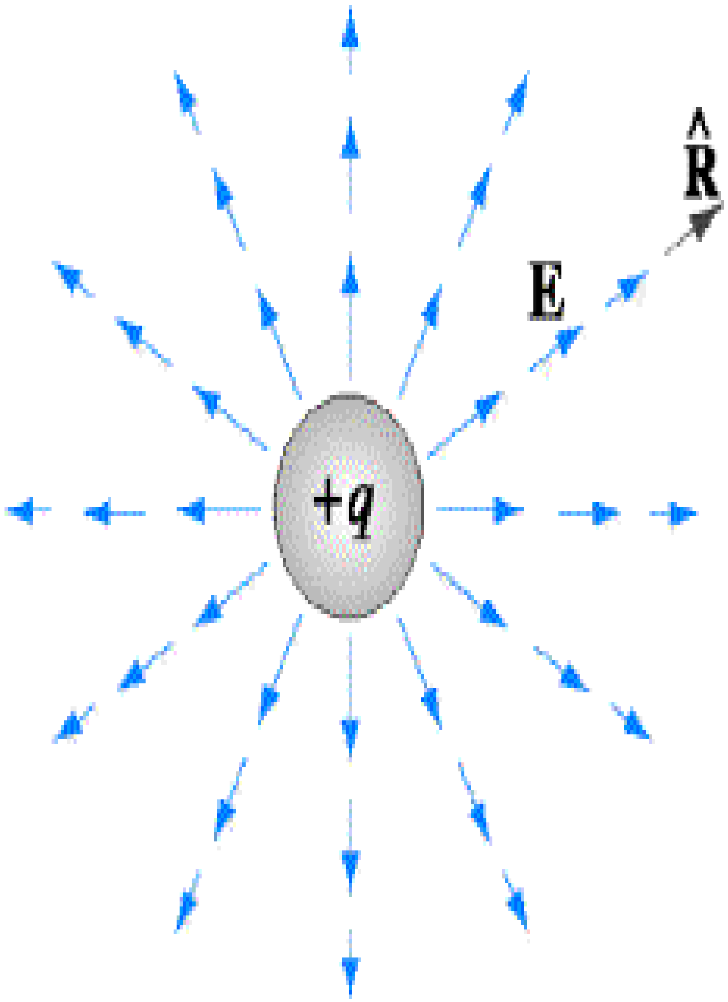
Improper electrical equipment/system design – incorrect modifications or using legacy equipment that doesn't meet current arc flash standards

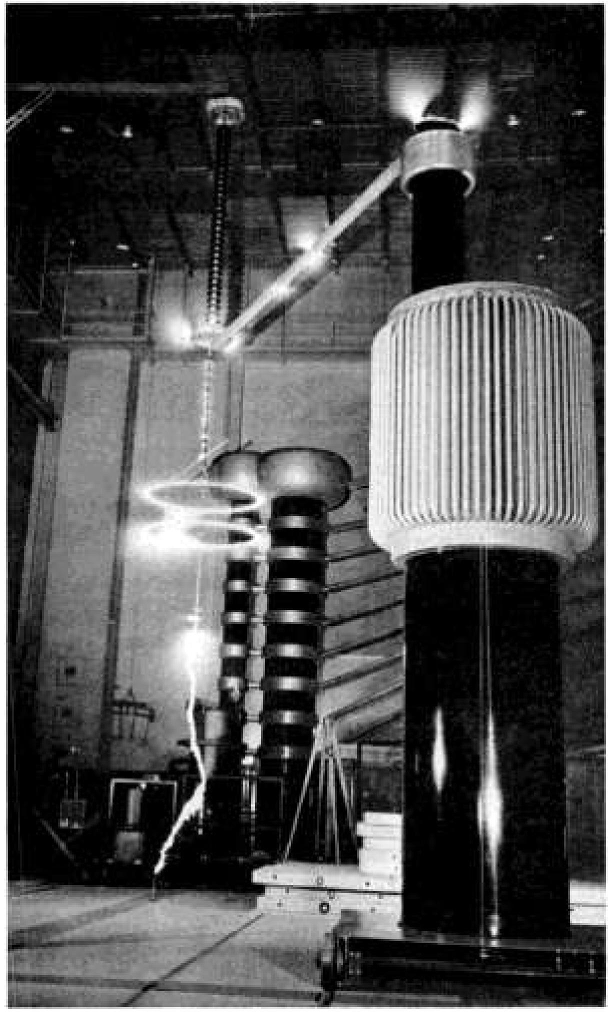
Conditions - dusty, dirty, wet environment.

Power Line Safety



Electric Force Field



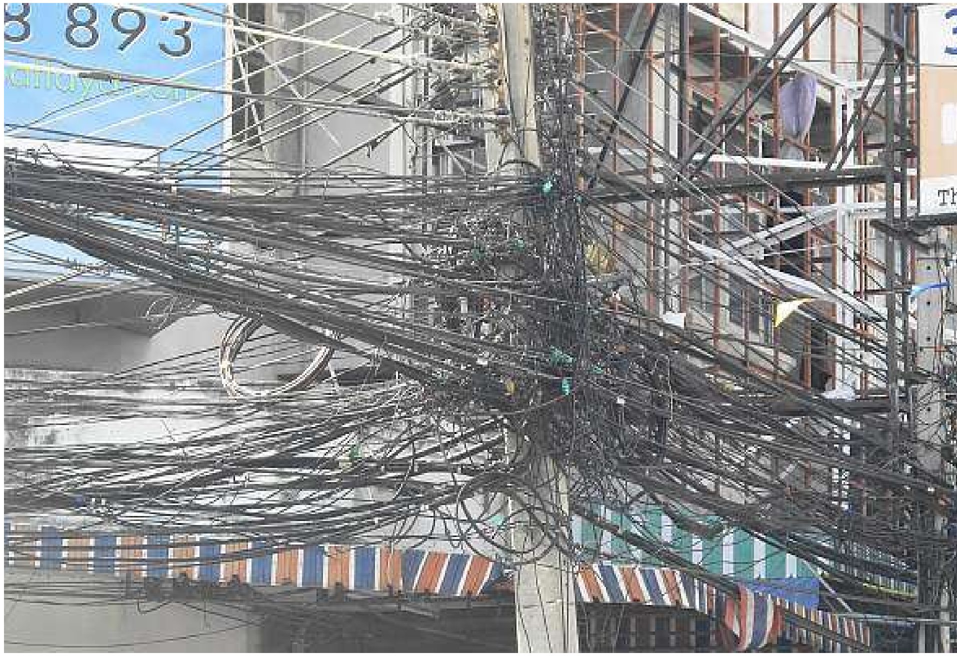


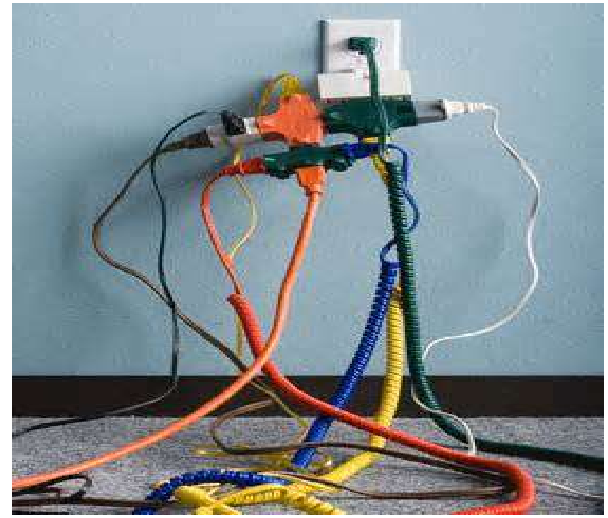
Why Are These Still Alive?

What Do You Do When You See This?

Careless and Stupidity

What Are the Problems In These Photos?





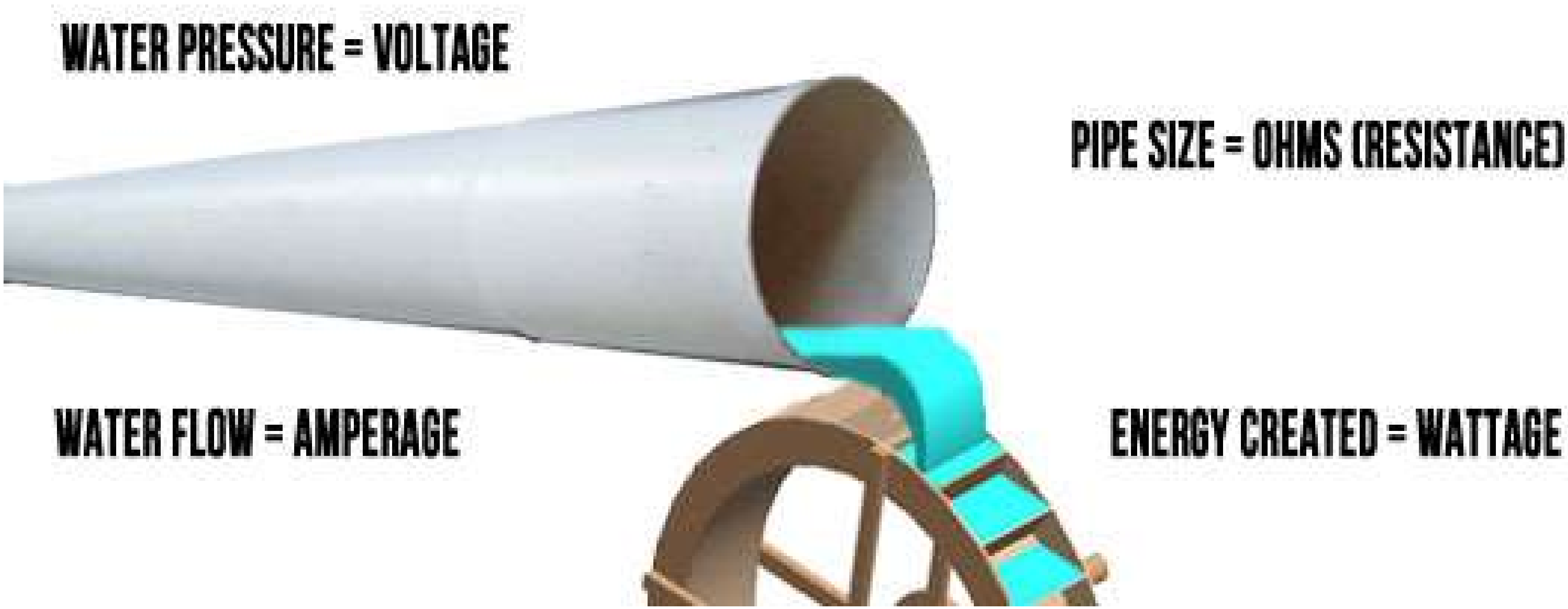
Quiz- Electrical Safety

- At what current level does the human heart go into ventricular fibrillation? What is the current level of the standard household outlet?
- What are your two best safety friends?
- List the four PPE components (Personal Protection Equipment).
- Does a GFI (GFCI) need a ground wire to operate?
- What is an arc flash? List common causes of an arc flash.
- What is the closest distance you can work to a live power line?

Quiz- Electrical Safety

- At what current level does the human heart go into ventricular fibrillation? 0.1 amp. What is the current level of the standard household outlet? 15 amps.
- What are your two best safety friends? PPE, Lockout GFI
- List the four PPE components (Personal Protection Equipment). Helmet/face protection, safety glasses, gloves, cotton/fire resistant clothing, boots.
- Does a GFI (GFCI) need a ground wire to operate? No. GFI monitors hot & neutral, trips at >5mA
- What is an arc flash? Flashover through air List common causes of an arc flash. Human error, maintenance, dust, dirt
- What is the closest distance you can work to a live power line? 10 ft

Electricity Characteristics



AMPS is amount of electricity (gallons of water).
VOLTS is the push (water pressure).
OHMS slows the flow (friction).
WATTS is how much work gets done.

1. The Volt

The pressure that is put on free electrons that causes them to flow is known as electromotive force (EMF). The volt is the unit of pressure, i.e., the volt is the amount of electromotive force required to push a current of one ampere through a conductor with a resistance of one ohm. Equivalent to **psi** in water.

2. The Ampere

The ampere defines the flow rate of electric current. For instance, when one coulomb (or 6 x 10^18 electrons) flows past a given point on a conductor in one second, it is defined as a current of one ampere (amp). Equivalent to **cfs, gpd** in water.

3. The Ohm

The ohm is the unit of resistance in a conductor. Three things determine the amount of resistance in a conductor: its size, its material, e.g., copper or aluminum, and its temperature. A conductor's resistance increases as its length increases or diameter decreases. The more conductive the materials used, the lower the conductor resistance becomes. Conversely, a rise in temperature will generally increase resistance in a conductor. Equivalent to surface roughness (friction) in water pipes.

4. The Watt

The watt is a rate of work. One watt is the rate at which work is done when one ampere (A) of current flows through an electrical potential difference of one volt (V).

Power Law

<u>Water</u> **<u>Electricity</u>**

head x flow = Power = pressure x flow

Head x flow x factor = Watts = Volts x Amps x factor

ignoring resistance - friction in water, ohms in electricity

Electricity – Remember as the West Virginia Law (WVA):

W = VA

Watts = Volts x Amps

Electricity – Resistance.

The unit of measurement for resistance is called the Ohm , and is indicated by the Greek letter Omega (Ω).

4 factors determine the resistance of a material:

(1) Type of Material (Water- roughness of pipe)

The resistance of various types of materials are different. For instance, copper is a better conductor of electricity than gold, and therefore has less resistance.

(2) Length (Water – length of pipe)

The resistance of a material is directly proportional to its length. The longer the material is, the more resistance it has. This is because the electrons must flow through more material, and therefore meets more friction over the entire distance.

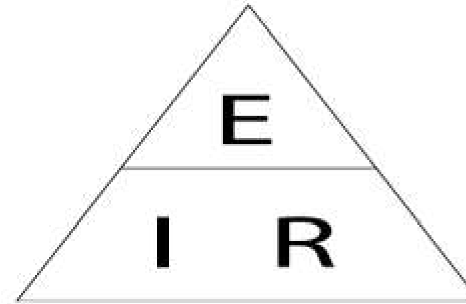
(3) Cross Sectional Area (Water – diameter of pipe)

The resistance of a material is inversely proportional to the cross sectional area of the material. This means that the thicker the substance is across, the lower the resistance. This is because the larger the cross sectional area is, the less friction there is over a given length

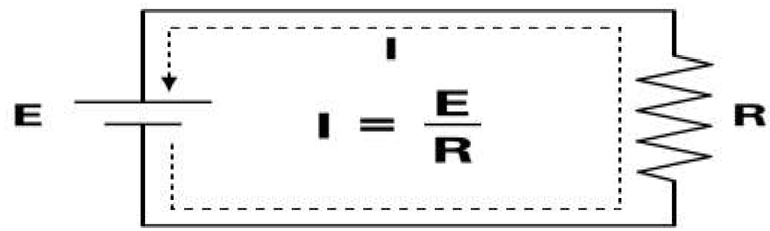
(4) Temperature

In various types of materials, resistance can vary inversely or directly with the temperature. This is because of the chemical properties of the material. In Carbon, for instance, the resistance decreases as the temperature rises. So we say it varies inversely. In copper, however, the opposite is true, with the rise in temperature, we have a rise in the resistance.

Ohms Law

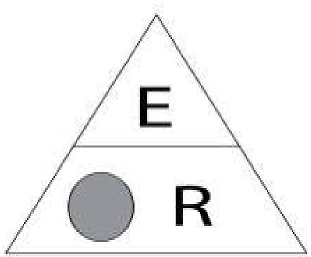


Ohm's law shows that current varies directly with voltage and inversely with resistance.

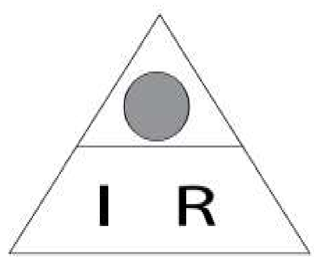


Current (I) is measured in amperes (amps)
Voltage (E) is measured in volts
Resistance (R) is measured in ohms

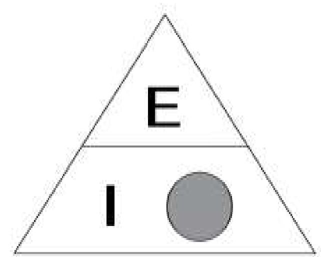
To use the triangle, cover the value you want to calculate. The remaining letters make up the formula.



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



$E = I \times R$



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

Unit	Symbol	Equivalent Measure
kilovolt	kV	1 kV = 1000 V
millivolt	mV	1 mV = 0.001 V
microvolt	μV	1 μV = 0.000001 V

Unit	Symbol	Equivalent Measure
kiloampere	kA	1 kA = 1000 A
milliampere	mA	1 mA = 0.001 A
microampere	μA	1 μA = 0.000001 A

Unit	Symbol	Equivalent Measure
megohm	MΩ	1 MΩ = 1,000,000 Ω
kilohm	kΩ	1 kΩ = 1000 Ω

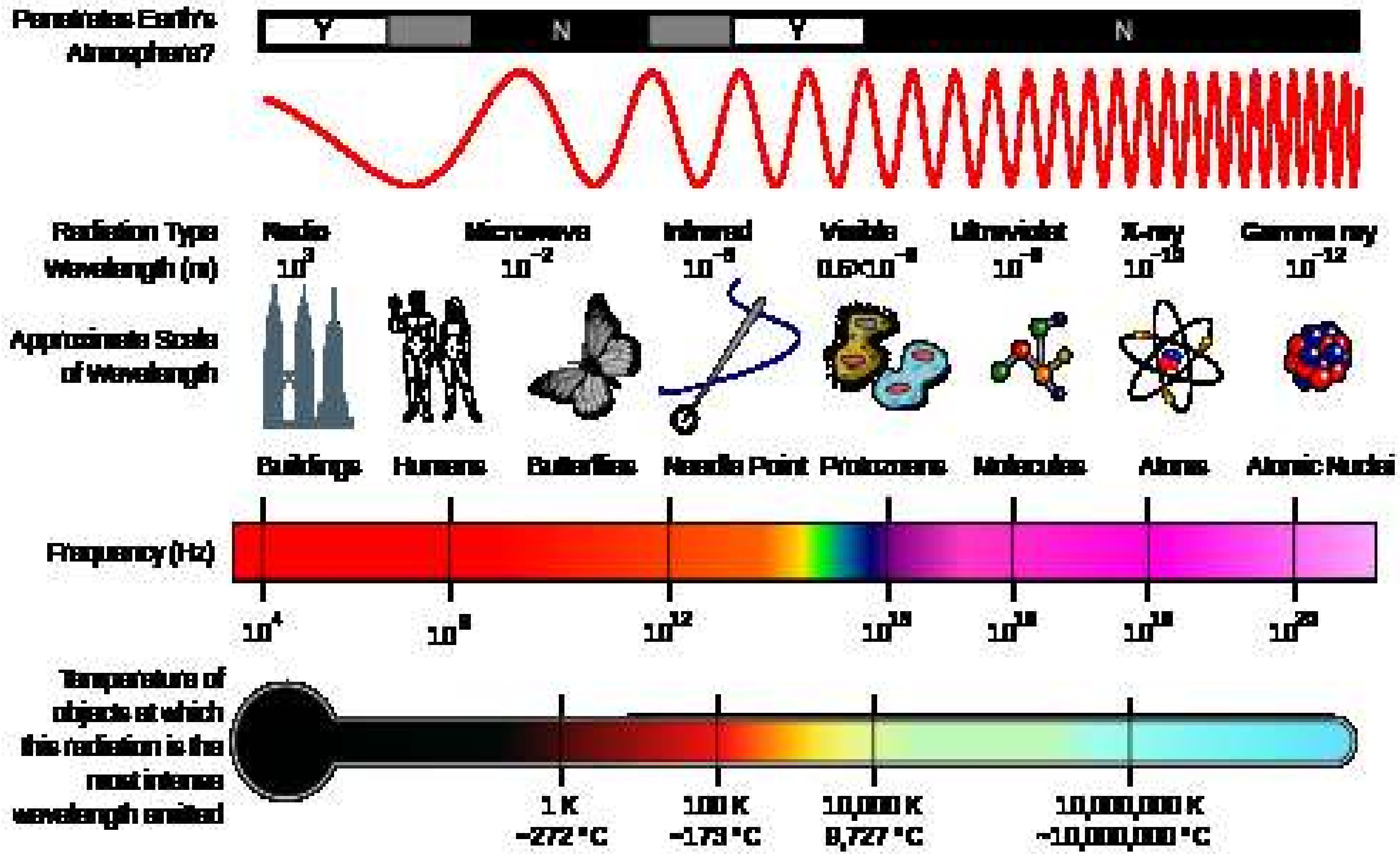
Quiz Electricity Characteristics

- Give the basic units of measurement for:
  - Resistance
  - Current
  - Voltage
  - Work
- What is one amp?
- If you have a household outlet of 15 amps and 120 volts, what is the maximum wattage it can provide?
- What are the four factors that influence electrical resistance?
- If you have a circuit that registers 10 ohms and has a voltage of 120 volts, what is the current?
- If a person walking across a carpet has picked up a static electricity charge of 35,000 volts, why aren't they hurt when it is discharged?

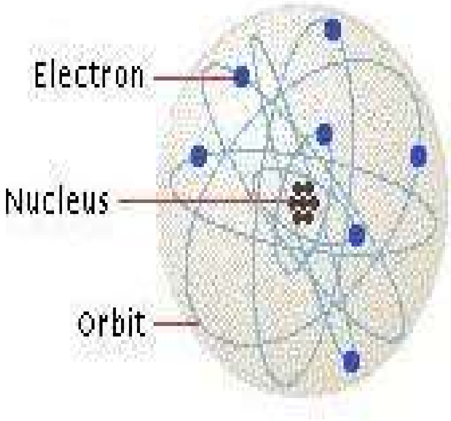
Quiz Electricity Characteristics

- Give the basic units of measurement for:
  - Resistance ohms
  - Current amps
  - Voltage volt
  - Work watt
- What is one amp? 6x10^18 electrons per second
- If you have a household outlet of 15 amps and 120 volts, what is the maximum wattage it can provide? w=va, 15a x 120v = 1800w
- What are the four factors that influence electrical resistance? Type material, length, cross section, temperature
- If you have a circuit that registers 10 ohms and has a voltage of 120 volts, what is the current? I=E/R = 120v/10ohms =12a
- If a person walking across a carpet has picked up a static electricity charge of 35,000 volts, why aren't they hurt when it is discharged? No amps

Electromagnetic Spectrum



Sources of Electricity (Movement of Electrons)



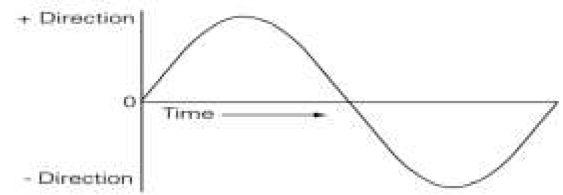
- Natural
  - Lightning (electrostatic discharge - can be >30,000 amps
  - ferroelectric
- Friction
  - static electricity
- Heat (thermoelectricity)
  - pyroelectric
- Chemical action
  - bioelectricity (movement, brain function, electroreception, electrogenic)
  - batteries
- Pressure
  - piezoelectric
- Light (photoelectricity)
  - photovoltaic
- Magnetism
  - Earth (including telluric currents)
  - Produced when a conductor moves through a magnetic field, or vice versa.

AC vs. DC

direct current (**DC**) is produced by batteries, fuel cells and solar cells (PV). The positive and negative terminals of a battery are always, respectively, positive and negative. Current always flows in the same direction between those two terminals.

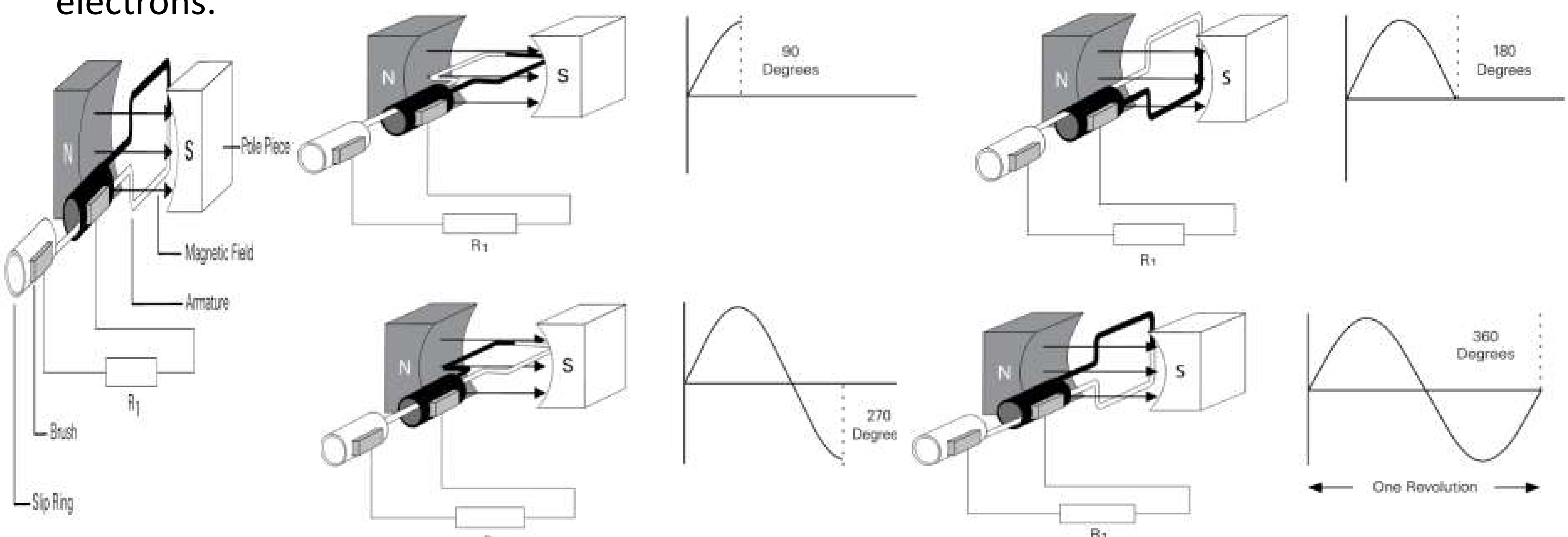
a**lternating current** (**AC**) is produced by most modern power plants. The direction of the current reverses, or alternates, 60 times per second (in the U.S.) or 50 times per second (in Europe, for example)..

AC Generation



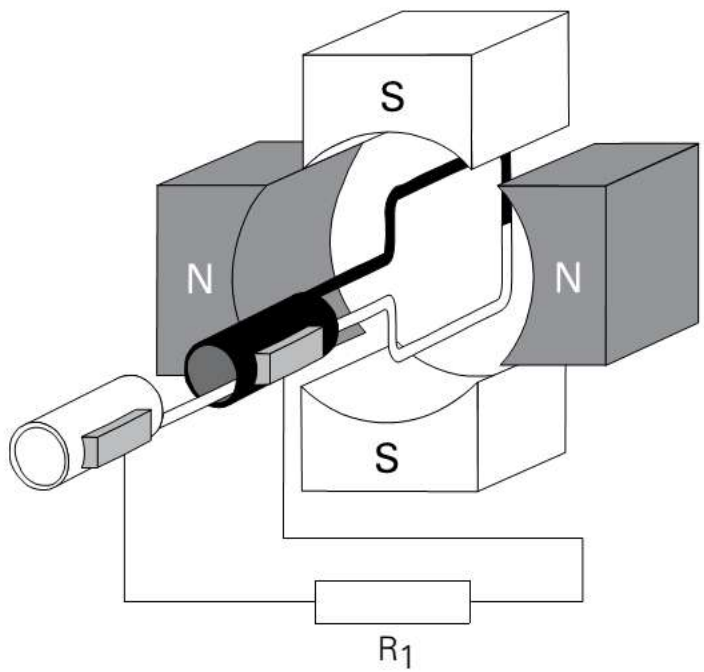
A **generator** is simply a device that moves a magnet near a wire to create a steady flow of electrons.

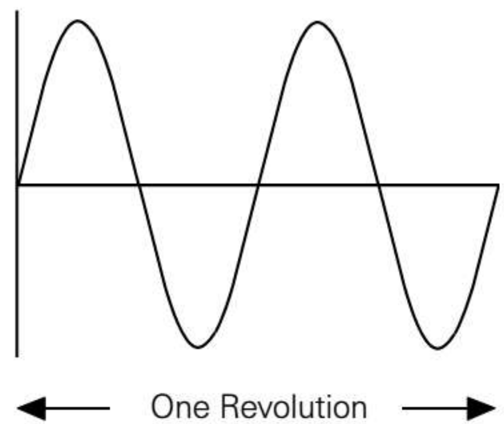
One simple way to think about a generator is to imagine it acting like a pump pushing water through a pipe. Only instead of pushing water, a generator uses a magnet to push electrons along. A water pump moves a certain number of water molecules and applies a certain amount of pressure to them. In the same way, the magnet in a generator pushes a certain number of electrons along and applies a certain amount of "pressure" to the electrons.



AC Generator Poles

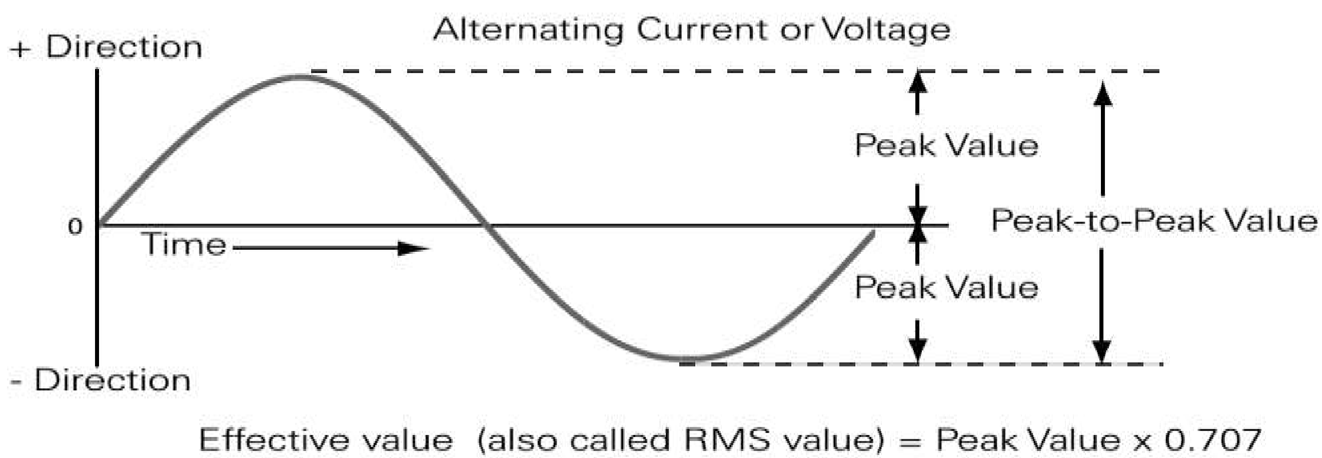
An AC generator produces one cycle per revolution for each pair of poles. An increase in the number of poles causes an increase in the number of cycles completed in a revolution. A two-pole generator completes one cycle per revolution and a four pole generator completes two cycles per revolution.





AC Characteristics

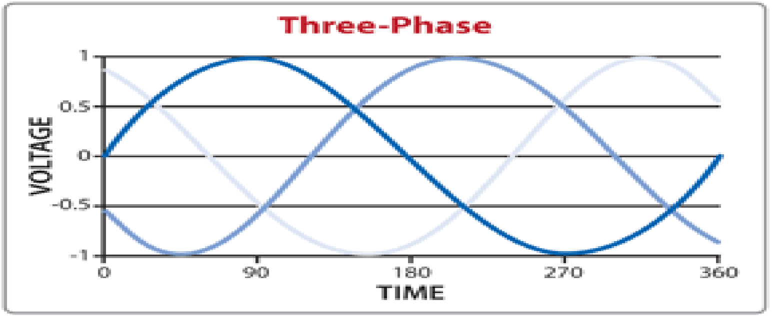
- **Frequency** The number of cycles per second of voltage induced in the armature is the frequency of the generator. If a two-pole. Generator armature rotates at a speed of 60 revolutions. Per second, the generated voltage have a frequency of 60 cycles per second. The recognized unit for frequency is hertz, abbreviated Hz. 1Hz is equal to cycle per second.
- **Amplitude** is the range in variation of a sine wave. The peak value of a sine wave is the maximum value for each half of the sign wave. The peak to peak value is the range from positive peak to the negative peak. The effective value of AC is defined in terms of equivalent heating value were compared to DC. The effective value of AC voltage or current is approximately 0.707 times the peak value. The effective value also referred to as the RMS value - is the root mean squared value.

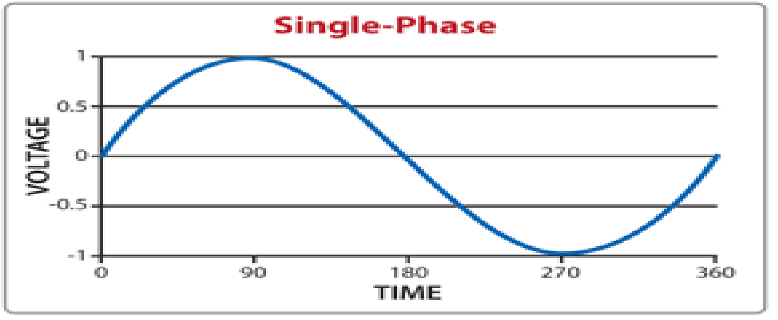


Single Phase vs. Three Phase

Single-phase AC voltage with zero power factor has both voltage and current sine waves in phase, so they cross the zero line together twice in each cycle. Transferred via two lines.

The sine waves of **three-phase voltage** are separated by *120 electrical degree* because they are generated by three separate sets of armature coils in an AC Generator. Transferred via three lines.



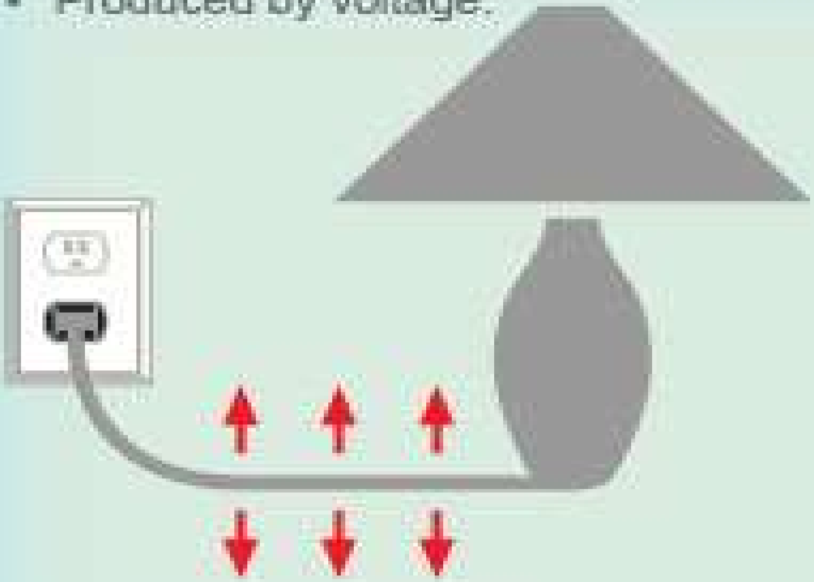


Three-phase machines and controls can be smaller, lighter in weight, and more efficient than comparable single-phase equipment. More power is supplied to them in the same period than can be supplied by a single-phase power circuit (about 73% more). However, the trade-off for this advantage is that three-phase machines and controls are more complex and expensive.
Only about 75 percent as much copper wire is required for distributing three-phase power as is required for distributing the same amount of single-phase power.

A Comparison of Electric and Magnetic Fields

Electric Fields

- Produced by voltage.

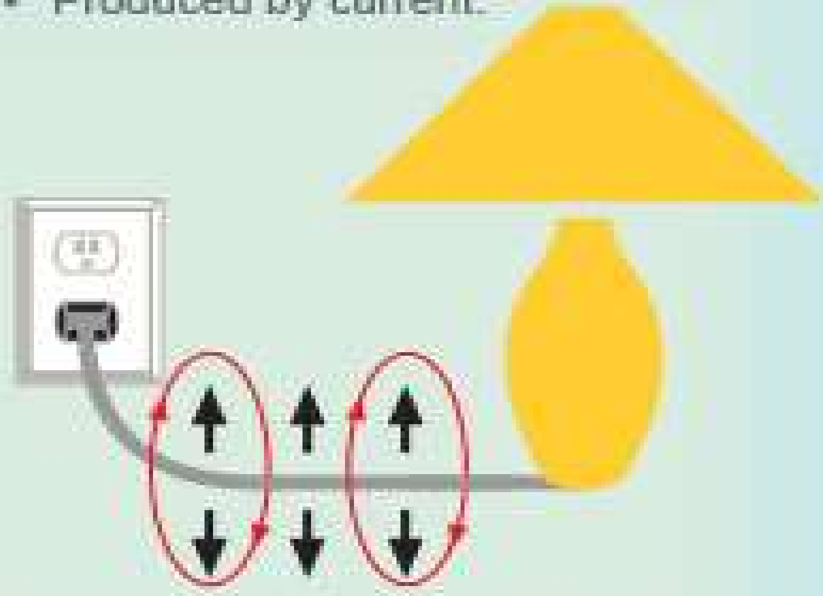


Lamp plugged in but turned off. Voltage produces an electric field.

- Measured in volts per meter (v/m) or kilovolts per meter (kV/m).
- Easily shielded (weakened) by conducting objects such as trees and buildings.
- Strength decreases rapidly with increasing distance from the source.

Magnetic Fields

- Produced by current.



Lamp plugged in but turned on. Current now produces a magnetic field also.

- Measured in gauss (G) or tesla (T)
- Not easily shielded (weakened) by most material.
- Strength decreases rapidly with increasing distance from the source.

Quiz. Electricity Production

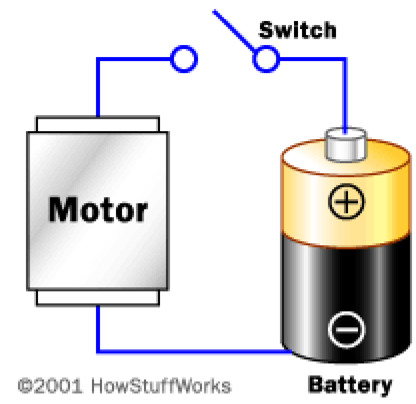
- What are the seven common sources of electricity?
- What is a characteristic representative of AC voltage or current values over time?
- An AC generator produces how many cycles per second revolution for each pair of poles?
- In three phase power, the sine waves are how many degrees out of phase with each other?
- Why would you choose a three phase motor over a single phase motor?
- Electric fields are produced by ______, magnetic fields are produced by _______.

Quiz. Electricity Production

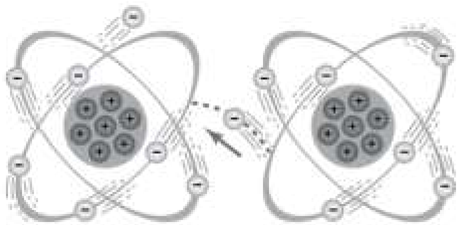
- What are the seven common sources of electricity? Natural, friction, heat, chemical, pressure, light, magnetism
- What is a characteristic representative of AC voltage or current values over time? Sine wave
- An AC generator produces how many cycles per second revolution for each pair of poles? One
- In three phase power, the sine waves are how many degrees out of phase with each other? 120 degrees
- Why would you choose a three phase motor over a single phase motor? Smaller, lighter, more efficient, more power
- Electric fields are produced by _voltage______, magnetic fields are produced by ___current____.

Electrical Conduction

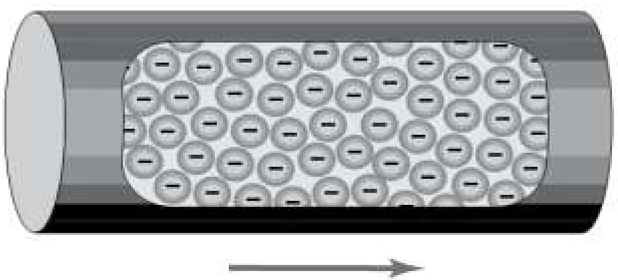
The source of electricity must have two terminals: a positive terminal and a negative terminal.
The source of electricity (whether it is a generator, battery or something else) will want to push electrons out of its negative terminal at a certain voltage. For example, one AA battery typically wants to push electrons out at 1.5 volts.
Electricity Flows in a Circuit .The electrons will need to flow from the negative terminal to the positive terminal through a copper wire or some other conductor. When there is a path that goes from the negative to the positive terminal, you have a **circuit**, and electrons can flow through the wire.



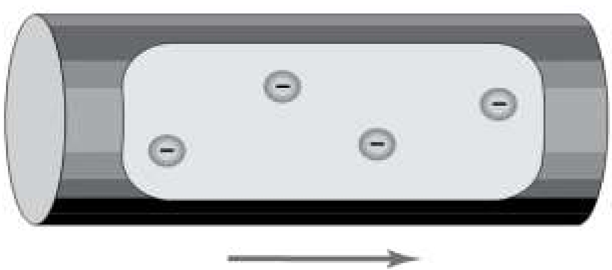
Electricity – Conductors and Insulators



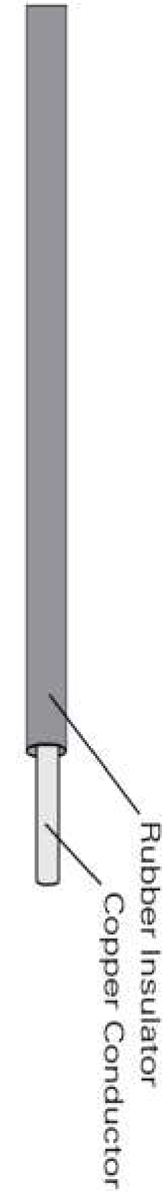
Electric current is produced when electrons move from atom to atom in a material.



Conductors permit the free flow of electrons. Good conductors are copper, silver, gold, aluminum, zinc brass, iron.



Insulators are resistant to the flow of electrons. Good insulators are dry air, plastic, rubber, glass, mica, and ceramic.



Inductance and Capacitance

Inductance is the property of an electric circuit that opposes any change in electric current. Resistance (ohms) opposes current flow, inductance opposes changes in current flow. The. unit of measurement for inductance is the henry (h).

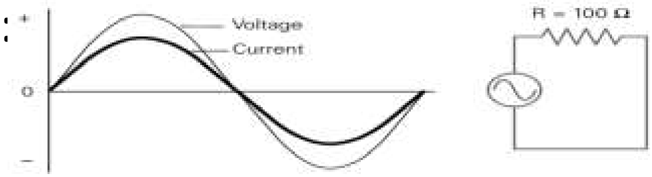
Unit	Symbol	Equivalent Measure
millihenry	mh	1 mh = 0.001 h
microhenry	µh	1 µh = 0.000001 h

Capacitance is a measure of a circuit's ability to store an electrical charge. A device manufactured to have a specific amount of capacitance is called a capacitor. The unit of measurement is the farad (F).

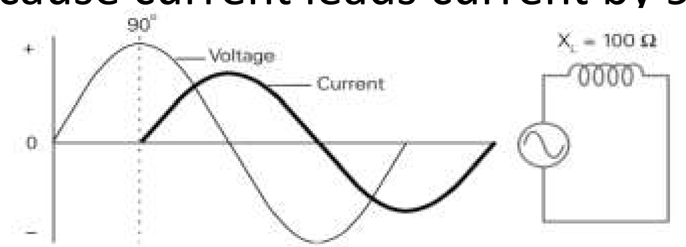
Unit	Symbol	Equivalent Measure
microfarad	µF	1 µF = 0.000001 F
picofarad	pF	1 pF = 0.000000000001 F

Reactance and Impedance

In a purely resistance AC circuit, such as with resistance heating, **resistance** is the only opposition to current flow. Current and voltage are in phase because they rise and fall at the same time:

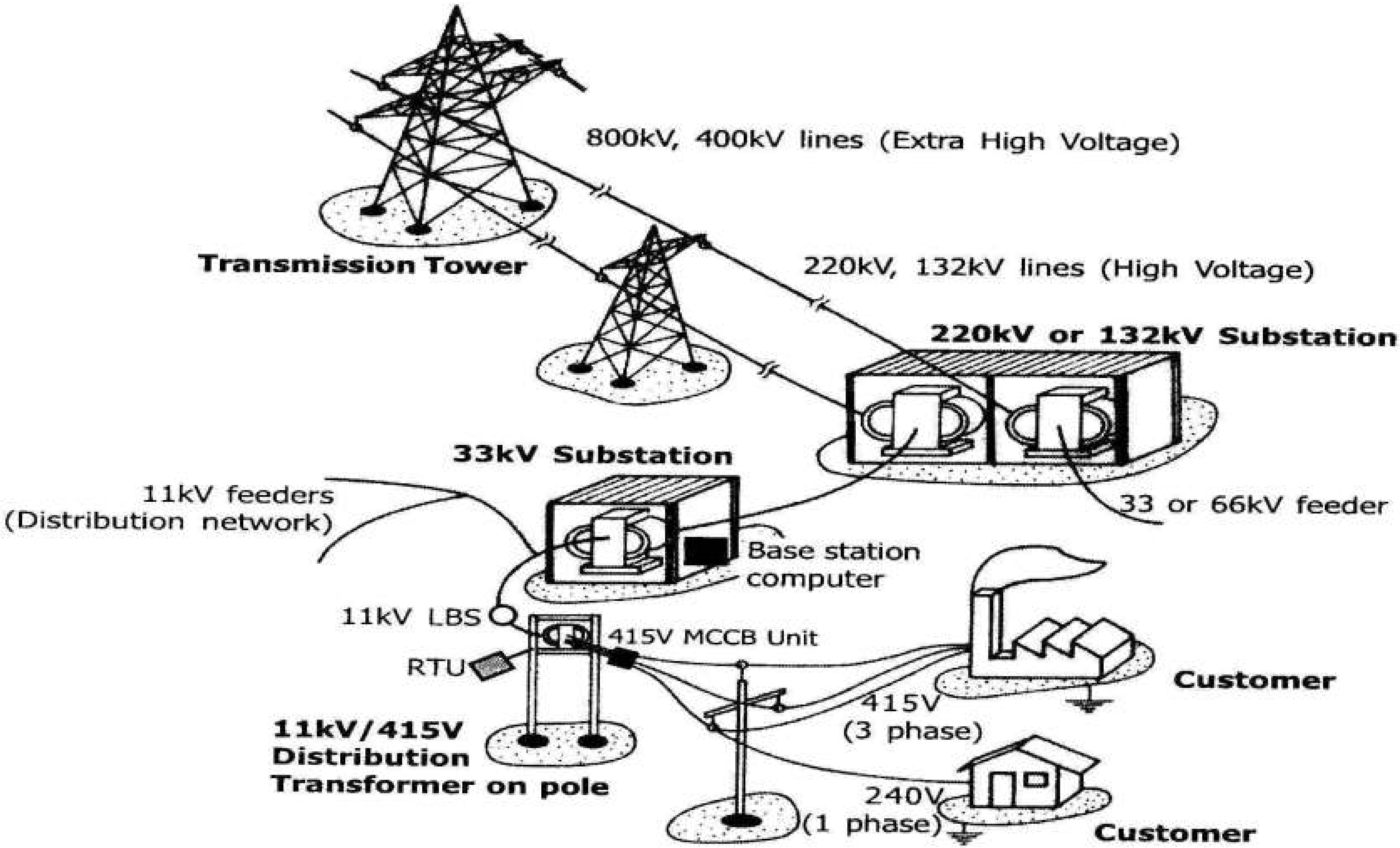


Reactance is the opposition to current flow in an AC circuit with only inductance, capacitance or both inductance and capacitance but no resistance. It is designated by the symbol X. In a purely inductive AC circuit, current and voltage are out of phase because current leads current by 90°.

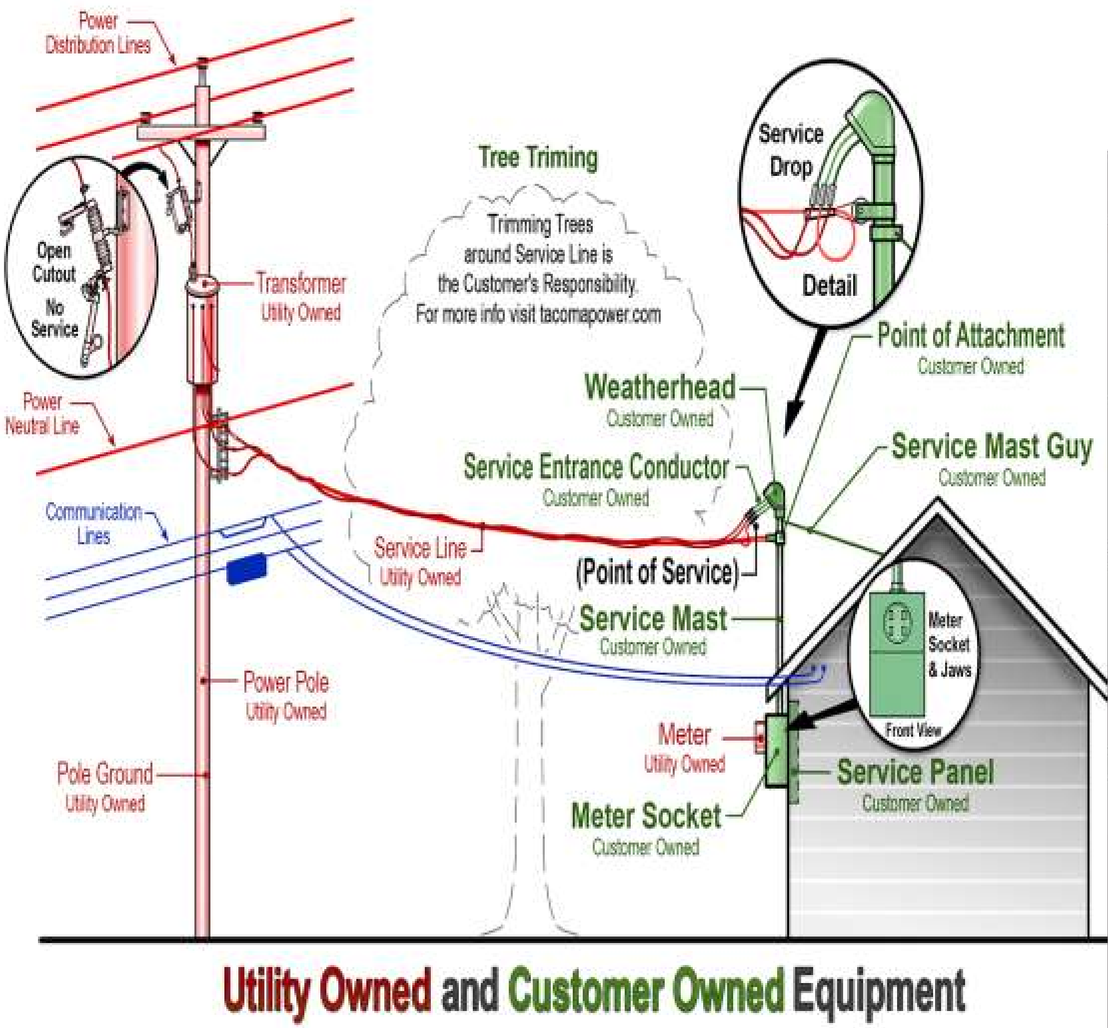


Impedance is the total opposition to current flow in an AC circuit that contains both reactance and resistance. It is designated by the symbol Z. In an AC circuit with both resistance and inductance, current lags voltage by more than 0° in less than 90°. The amount exact amount of lag depends upon the relative amounts of resistance and inductive reactants.

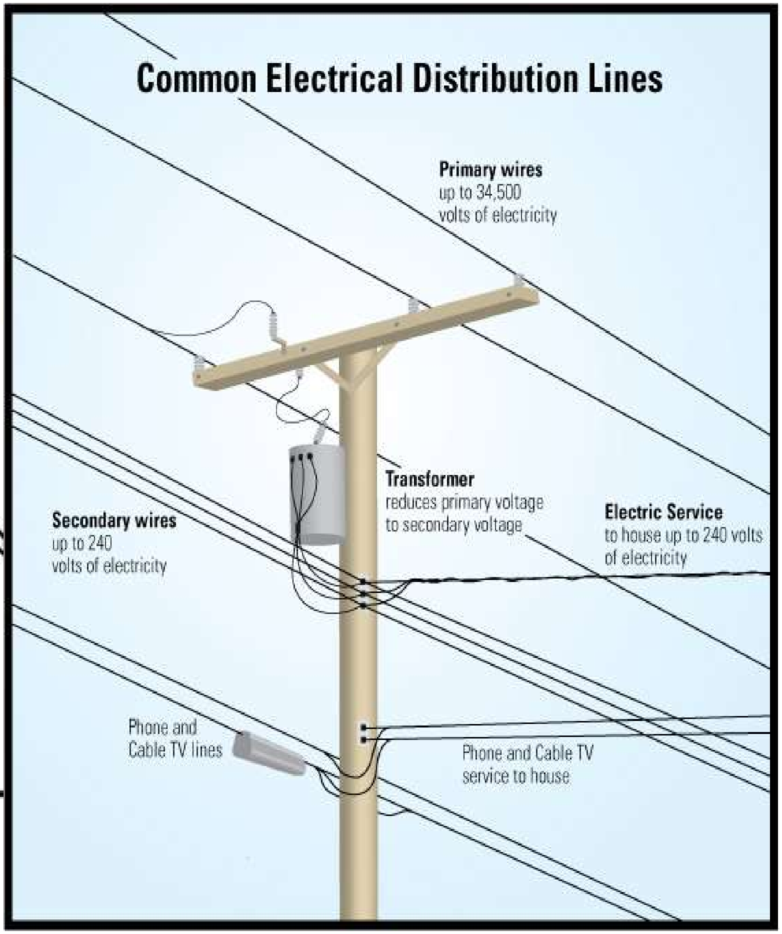
Electricity Conduction



Power Lines


Power Distribution Lines
Open Cutout
No Service
Transformer
Utility Owned
Power Neutral Line
Communication Lines
Tree Triming
Trimming Trees around Service Line is the Customer's Responsibility. For more info visit tacomapower.com
Service Drop
Detail
Point of Attachment
Customer Owned
Weatherhead
Customer Owned
Service Mast Guy
Customer Owned
Service Entrance Conductor
Customer Owned
Service Line
Utility Owned
(Point of Service)
Service Mast
Customer Owned
Meter Socket & Jaws
Front View
Power Pole
Utility Owned
Meter
Utility Owned
Service Panel
Customer Owned
Pole Ground
Utility Owned
Meter Socket
Customer Owned
Utility Owned and Customer Owned Equipment


DANGER
DO NOT OPERATE WITHIN 10 FT. OF POWER LINES

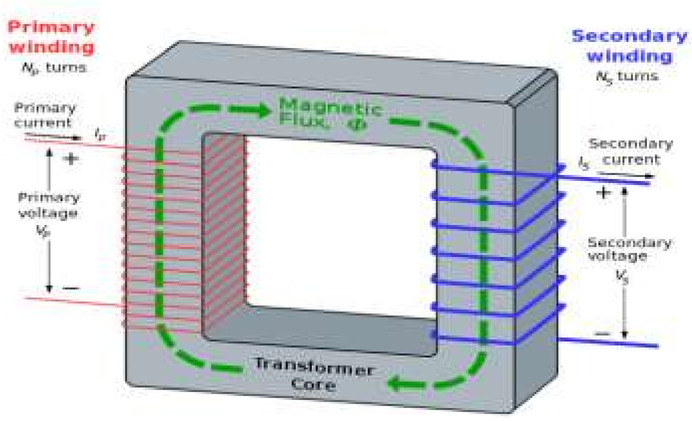

Common Electrical Distribution Lines
Primary wires
up to 34,500 volts of electricity
Transformer
reduces primary voltage to secondary voltage
Secondary wires
up to 240 volts of electricity
Electric Service
to house up to 240 volts of electricity
Phone and Cable TV lines
Phone and Cable TV service to house

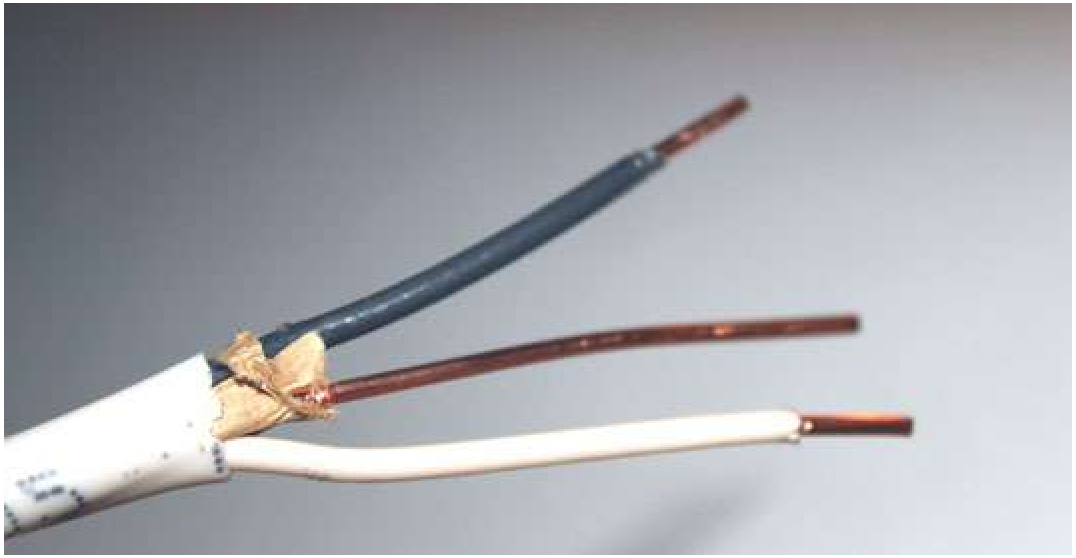
Transformers

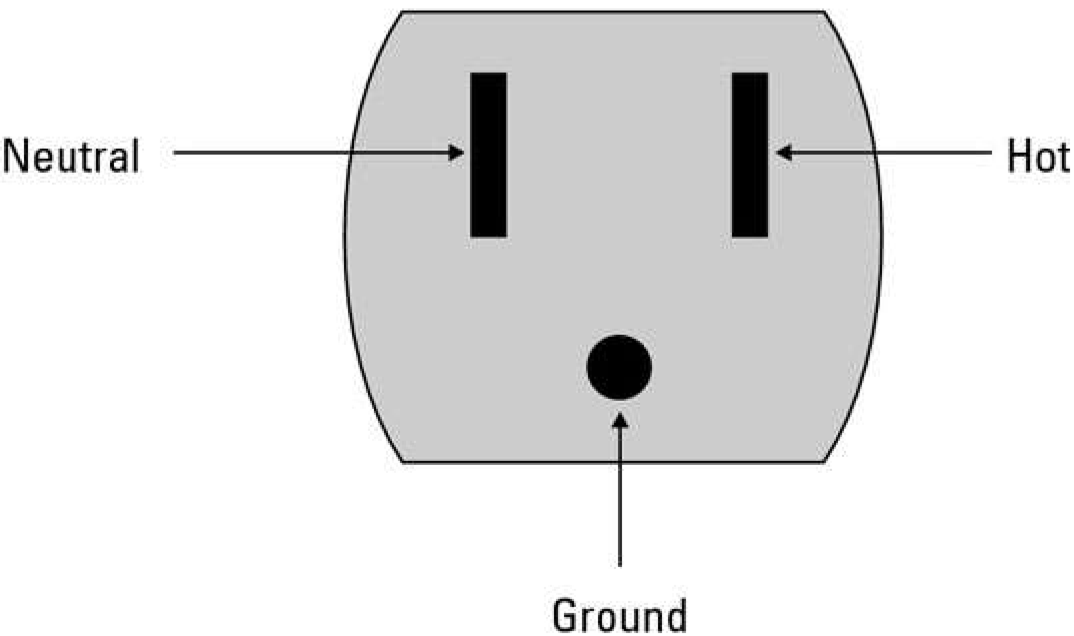
A **transformer** is an electrical device that transfers energy between circuits through electromagnetic induction. Transformers are used to step a voltage up to a higher level, or down to a lower level. They are like using pumps to increase pressure or pressure reduction valves to reduce pressure in a water system

A transformer most commonly consists of two windings of wire that are wound around a common core to provide tight electromagnetic coupling between the windings. The core material is often a laminated iron core. The coil that receives the electrical input energy is referred to as the primary winding, while the output coil is called the secondary There is a direct relationship between voltage, impedance, current, and the number of primary and secondary coil turns in a transformer.

-If the primary coil has fewer turns than the secondary
-coil, the transformer is a step-up transformer.
-If the primary coil has more turns than the secondary coil, the transformer is a step-down transformer.

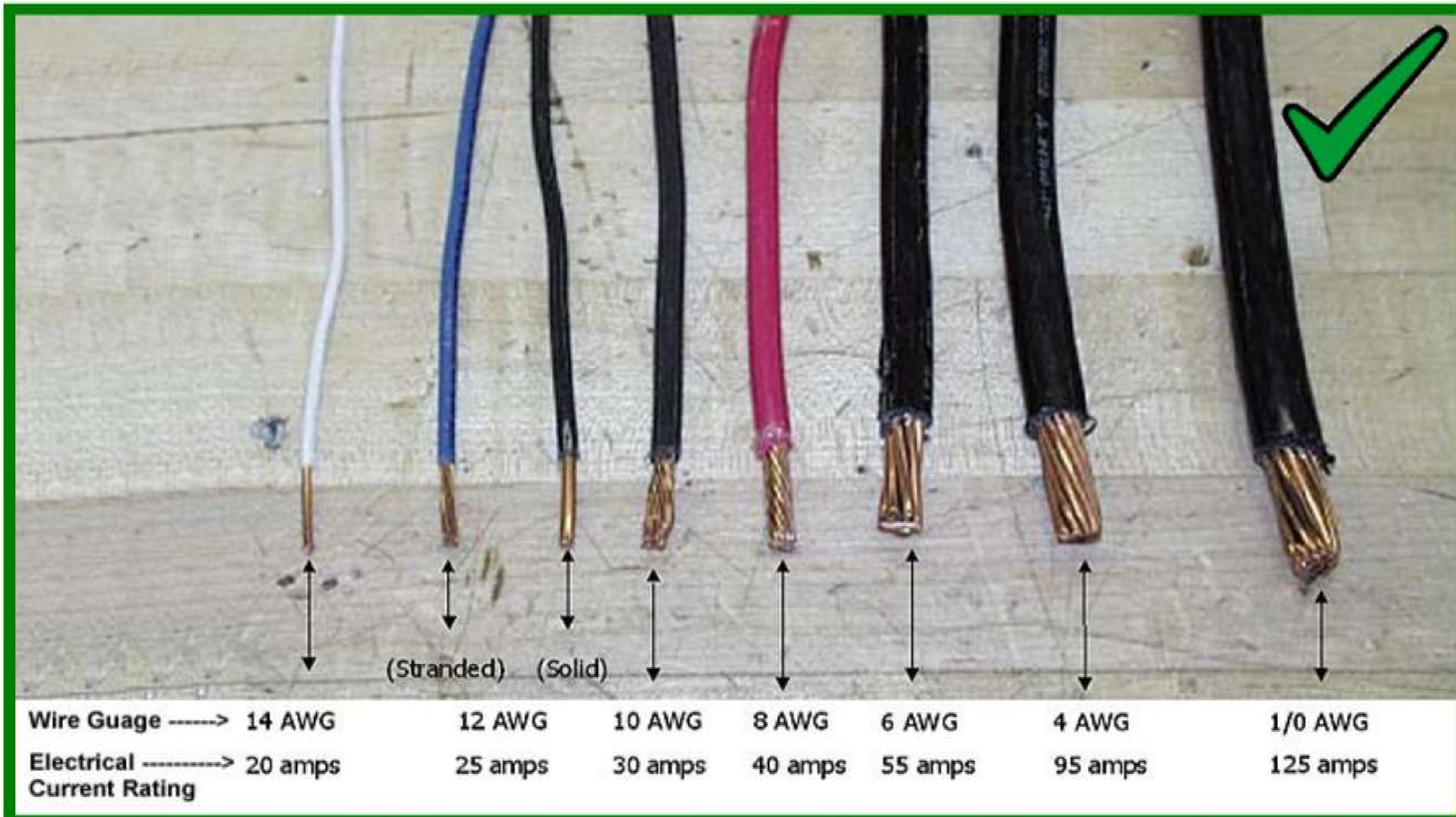






Hot: The black wire is the *hot wire*, which provides a 120 VAC current source.
Neutral: The white wire is called the *neutral wire*. It provides the return path for the current provided by the hot wire. The neutral wire is connected to an earth ground.
Ground: The bare wire is called the *ground wire*. Like the neutral wire, the ground wire is also connected to an earth ground. However, the neutral and ground wires serve two distinct purposes.
The neutral wire forms a part of the live circuit along with the hot wire. In contrast, the ground wire is connected to any metal parts in an appliance such as a microwave oven or coffee pot. This is a safety feature, in case the hot or neutral wires somehow come in contact with metal parts.
Connecting the metal parts to earth ground eliminates the shock hazard in the event of a short circuit.
Note that some circuits require a fourth conductor. When a fourth conductor is used, it's covered with red insulation and is also a hot wire.

DIFFERENT TYPES OF WIRES WITH THEIR ELECTRICAL CURRENT RATING

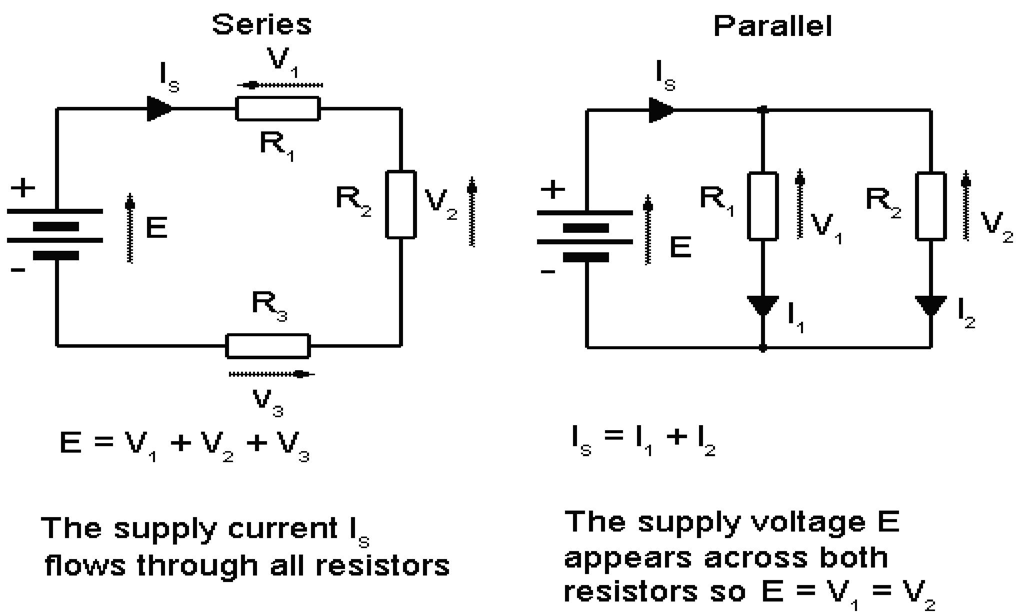


Conductors should be sized with voltage drops < 3%.

Fuses devices used to protect the electrical circuit from too much current flow. A fuse is designed to open the circuit when the current reaches a predetermined level. Fuses are rated in Amps. Do not install a fuse larger than is designed for the circuit.

A **relay** is a switch that changes states when voltage is applied to its input. When the coil is not energized a spring keeps the switch held open or OFF. These are used to direct electricity to a high current device like a starter motor, with the use of a light duty switch (key switch) and to control devices.

Parallel vs. Series Circuits



- In series circuits the voltage is additive, current is the same.
- In parallel circuits, the voltage is the same, the current is additive.

Quiz. Electrical Conduction

- What is inductance and capacitance in a circuit?

- What is reactance and impedance in a circuit?

- What does a step-down transformer do?

- Define hotwire, neutral wire, and ground wire.

- What does a fuse do? How does a relay operate?

- The smaller the wire gauge, the ________ the size and the ______ amps it will carry.

- You have four (4) 12v, 10Ah batteries. What is the voltage and current if they are wired in parallel and in series?

Quiz. Electrical Conduction

- What is inductance henry – opposition to changes in current flow and capacitance farad – ability to store electricity in a circuit?

- What is reactance opposition to current flow in AC circuit with no resistance and impedance total opposition to current flow in circuit with reactance and resistance in a circuit?

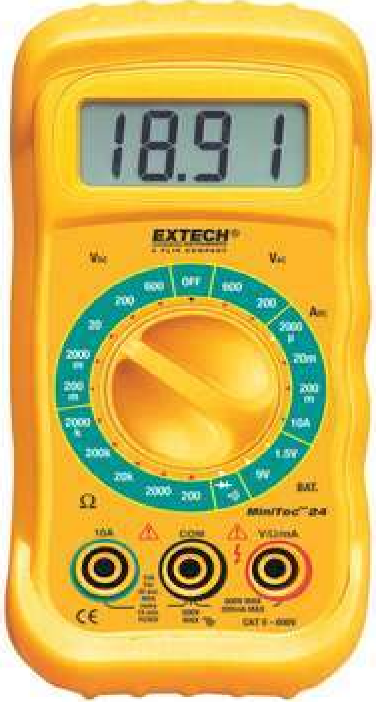
- What does a step-down transformer do? Reduces voltage. Primary coil has more turns than secondary coil.

- Define hotwire ac current source, neutral wire return path, and ground wire to ground.

- What does a fuse do? Protect from excess current flow. How does a relay operate? Closes with voltage

- The smaller the wire gauge, the _larger__ the size and the __more___ amps it will carry.

- You have four (4) 12v, 10Ah batteries. What is the voltage and current if they are wired in parallel and in series? Series: 48V @ 10Ah, parallel: 12v @ 40Ah.



Multimeters typically have at least have three settings- current, voltage, and resistance. More expensive ones test for continuity, capacitance, and inductance.

Noncontact voltage detector – tick tracer

Receptacle Tester for Detecting Faulty Wiring In (3) Wire Receptacles and (5) Wiring Faults

Clamp meter is designed for measuring higher currents without putting either you or your meter at risk of shock. Measures current, voltage, and resistance.

Solenoid Voltage Meter (Wiggy) reads voltage, both for alternating and direct current. Ranges this type of meter is able to read are from 120 to 600 volts.

Troubleshooting

- Voltage drop- the difference in voltage potential when measured across a circuit or component creating resistance

-Voltage Drop- “Resistance decreases the amount of voltage available.”

- Resistance- an opposing force, created by a circuit or component, to the flow of electrical current

-Resistance- “There is a small amount of natural resistance when voltage flow through wires, switches, grounds or connections. The resistance increases beyond acceptable limits if corrosion develops, fittings become loose or wires fray. Resistance increases each time something, such as a wire, a switch, connections, or the ground are added to the circuit.”

- Harnesses   Suspected defect in a wire
  - test for continuity with an ohm meter or multimeter. Make sure power is off.
  - after checking for continuity, check for a short to nearby pins, battery ground and battery positive

- Switches   Test leads on correct pins
  - With wires disconnected from the switch, connect ohm meter across the switch. With the switch open you should read infinite ohms. With the switch closed you should read zero ohms. Anything other than these readings indicates a faulty switch
  - Switch can often be tested with a voltmeter in a live circuit

Relays –

- Replace relay with a known good relay
    - quick and effective.

- Remove relay and put a jumper across correct pins to simulate a closed switch

    –if output circuit functions, the circuit is ok

•Test activation signal

    –May be able to test for activation signal by listening to the relay

    –Test switch output

        –same test for any other switch

        –activate the relay and check that the switch functions properly

-Activation Signal- When activated and or deactivated, many relays make a clicking sound. If the clicking sound is present, you can generally assume that the activation signal is present. A more positive method is to check for ground and the correct activation signal at the relay using a volt meter. If you do not have the activation signal, the relay coil was shorted and should be replaced

- Modules / Controllers
- First, check for correct ground and power to module
- If a known good module is available, replacement is the best test
- Observe symptoms
- Often controllers are expensive
  - casual controller replacement is not recommended

-Because modules often are complex internally and perform many functions, it can be difficult to determine if a problem exists.

Spot the Trouble

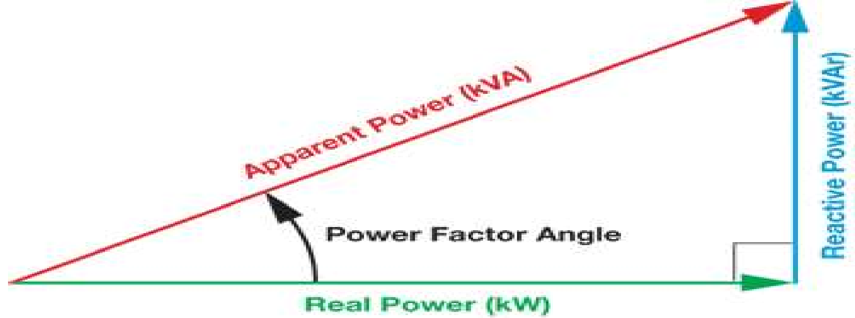
Quiz. Troubleshooting

- What does a “wiggy” (solenoid tester) do?
- How do you test for resistance?
- How do you check a relay? What do you do when it is bad?
- When would you use a clamp meter instead of a probe multimeter?
- When performing a continuity test, what do you look for?
- How do you test a switch?

Quiz. Troubleshooting

- What does a “wiggy” (solenoid tester) do? reads voltage
- How do you test for resistance? Look for voltage drop
- How do you check a relay? Using activation signal What do you do when it is bad? Replace it.
- When would you use a clamp meter instead of a probe multimeter? High current without direct contact
- When performing a continuity test, what do you look for? Use ohm meter, check if voltage and ohms are acceptable
- How do you test a switch? See if it works or use ohm meter – infinite if switch open, zero when switch closed.

Power Factor



AC power flow has the three components:

real power (also known as active power), measured in watts (W). This is the "true" or "real" power used in all electrical appliances to perform the work of heating, lighting, motion, etc,

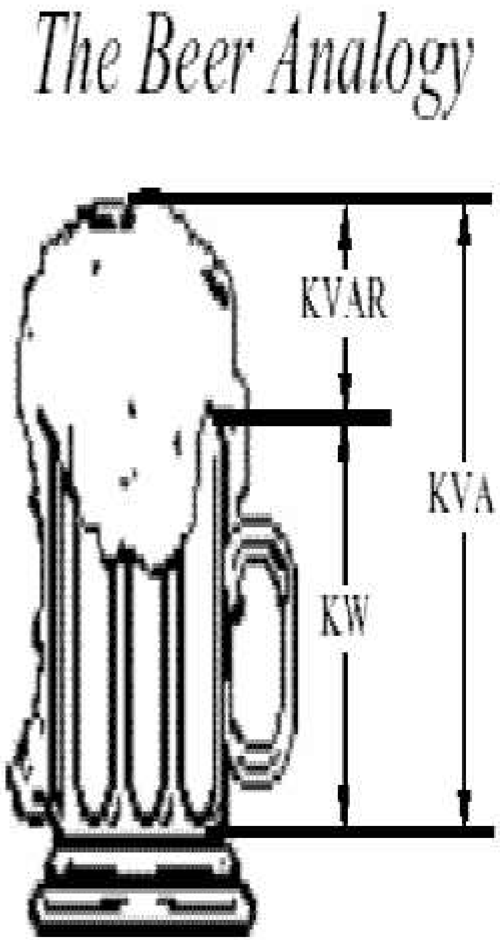
apparent power measured in volt-amperes (VA)

reactive power measured in reactive volt-amperes (kVar). It is the power that magnetic equipment (transformer, motor and relay) needs to produce the magnetizing flux.

An inductive load, like a motor, compressor or ballast, also requires **reactive power** to generate and sustain a magnetic field in order to operate. We call this non-working power kVAR's, or kilovolt-amperes-reactive.

Power factor is the ratio between true power, the KW (Kilowatts) and apparent power, the KVA (Kilo-Volt Amperes) {technically it is the cosine of the phase angel between current]and voltage]. It is a measure of how effectively the current is being converted into useful work output.

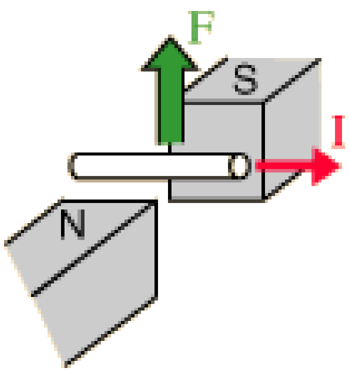
$$\text{Power Factor} = \frac{\text{Real Power (kW)}}{\text{Apparent Power (kVA)}} = \frac{\text{kW}}{\sqrt{(\text{kW})^2 + (\text{kVAr})^2}}$$



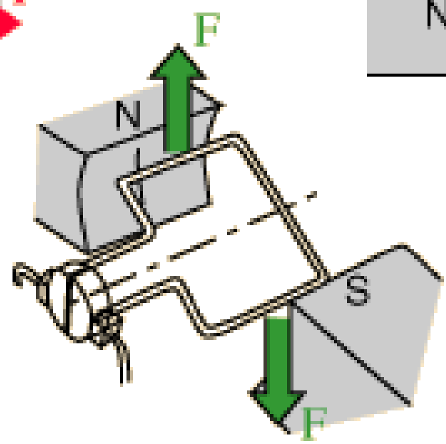
What causes a large KVAR in a system? The answer is…inductive loads. Inductive loads (which are sources of Reactive Power) include:

- Transformers
- Induction motors
- High intensity discharge (HID) lighting

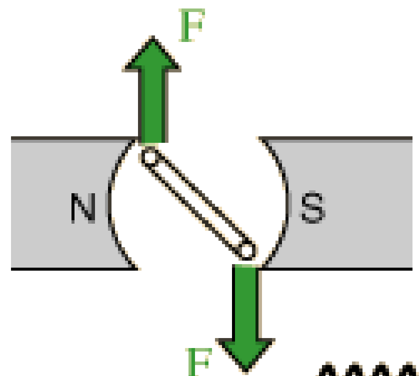
How Motors WORK



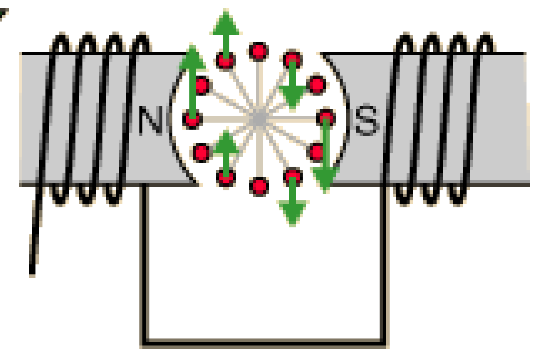
An electric current in a magnetic field will experience a force.



If the current-carrying wire is bent into a loop, then the two sides of the loop which are at right angles to the magnetic field will experience forces in opposite directions.



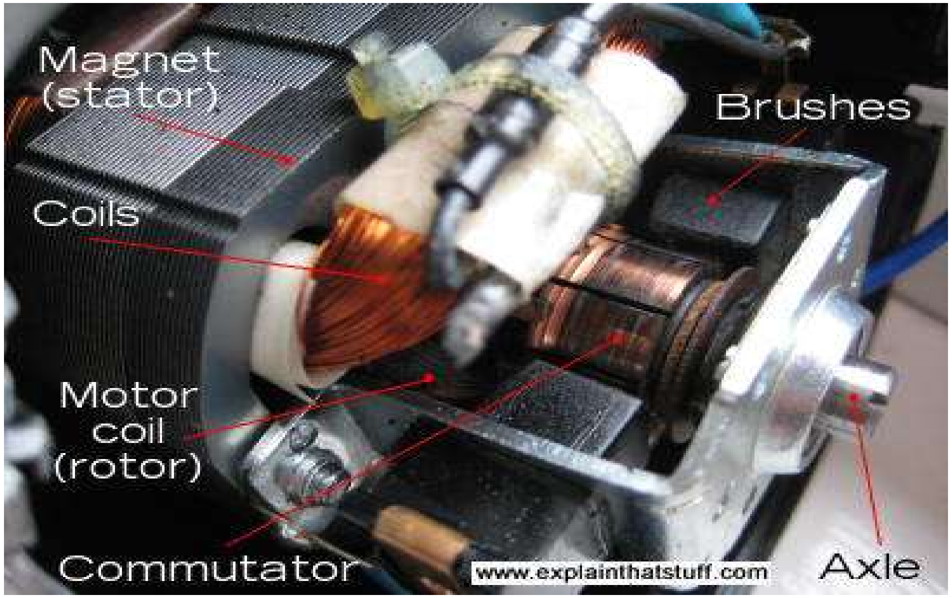
The pair of forces creates a turning influence or torque to rotate the coil.

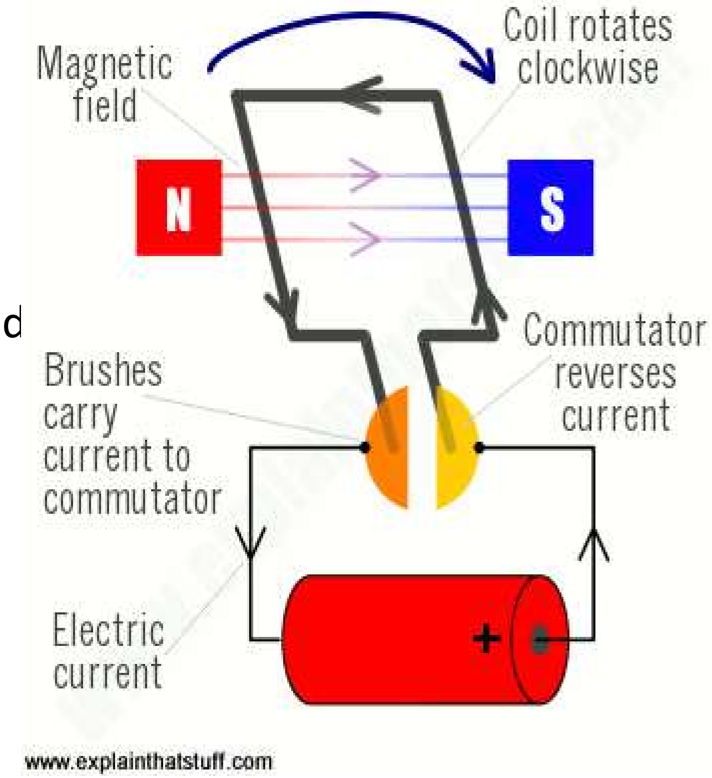


Practical motors have several loops on an armature to provide a more uniform torque and the magnetic field is produced by an electromagnet arrangement called the field coils.

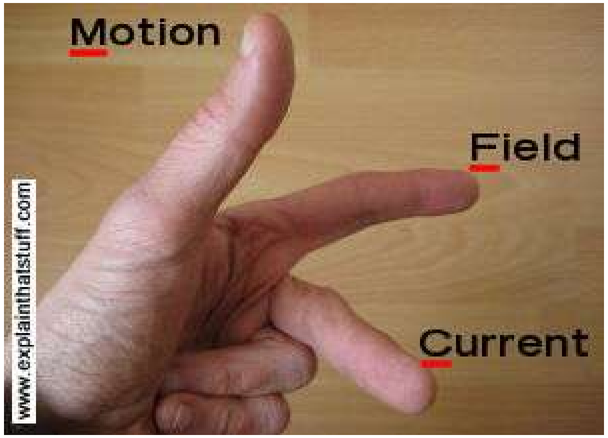
Electric Motors

An AC Motor/Generator Consists of 2 Main Parts:
A shaft-mounted wire wound armature (rotor)
A field of magnets that induce electrical energy stacked sid
by-side in a housing (stator)





<u>Flemings Left Hand Rule (Motor Rule)</u>
<u>F</u>irst finger = Field
Se**<u>C</u>**ond finger = Current
Thu**<u>M</u>**b = Motion



Low power factor is caused by inductive loads (such as transformers, electric motors, and high-intensity discharge lighting), which are a major portion of the power consumed in industrial complexes. Unlike resistive loads that create heat by consuming kilowatts, inductive loads require the current to create a magnetic field, and the magnetic field produces the desired work. The total or apparent power required by an inductive device is a composite of the following:

-Real power (measured in kilowatts, kW),

-Reactive power, the nonworking power caused by the magnetizing current, required to operate the device (measured in kilovars, KVA or kVAR).

Maximum Real Power for billing period = **1,000** kW

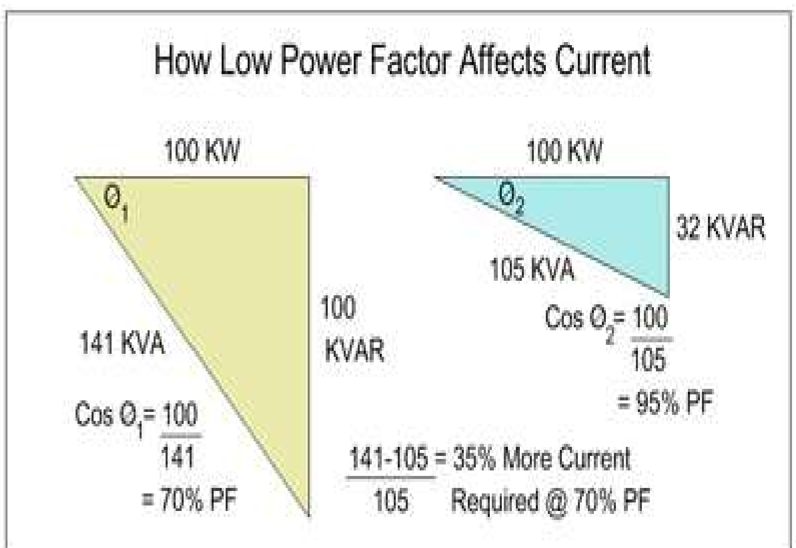
Reactive Power at the time of maximum kW demand = **750** kVAR

Apparent Power = SQRT [(1,000 kW)^2 + (750 kVar)^2] = **1,250** kVA

Power Factor = $\frac{\text{1,000 kW}}{\text{1,250 kVA}}$ = 0.80 = **80%**

Power Factor Correction

The power factor is the ratio of the real or active power flowing to a load divided by the apparent power in the circuit, and is a unitless number between 0 and 1. Real power kW- does work. Reactive power energizes magnetic fields (motors/pumps). In example below, current (amps) must increase by 35% to get the same amount of work done at 70% PF. Correct by installing power factor correction capacitors to provide reactive power (kVA).

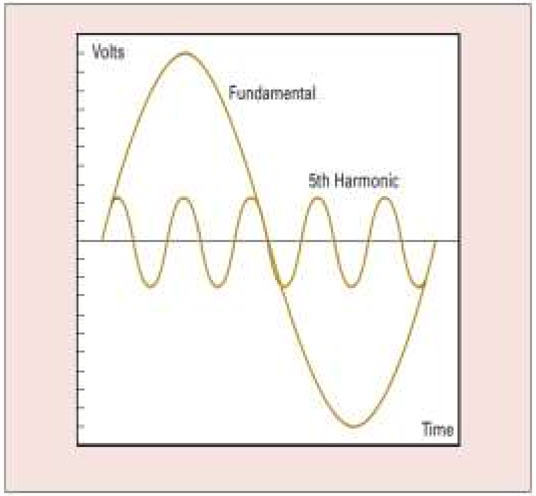


Harmonics

A harmonic is a *component of a periodic wave having a frequency that is an integral multiple* of the fundamental power line frequency of 60 Hz.

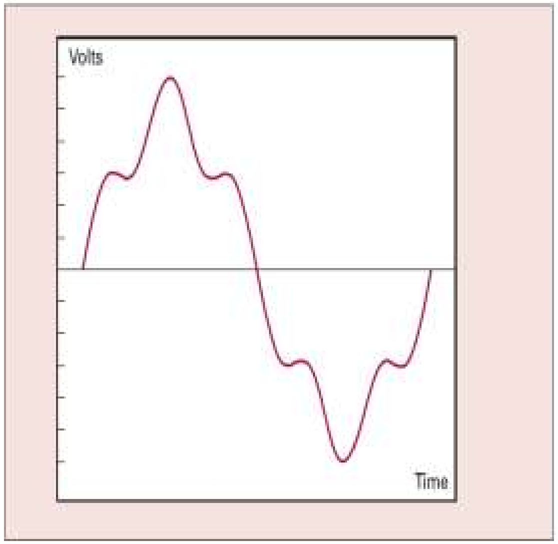
Linear loads have the current waveform closely matching sinusoidal voltage waveform and changing in proportion to the load. Linear devices include:

- Motors
- Incandescent lighting
- Heating loads



Nonlinear loads—which draw current at frequencies other than 60 HZ. Nonlinear devices include:

- DC drives
- Variable frequency drives
- Programmable controllers
- Induction furnaces
- Arc-type lighting
- Personal computers
- Uninterruptible power supplies (UPS



Capacitors and transformers can also cause resonance.

Harmonics

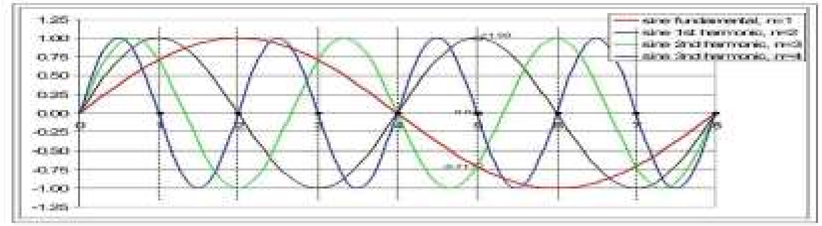


Table 9. Negative Consequences of Harmonics on Plant Equipment

Equipment	Consequences
Current Harmonic Distortion Problems	
Capacitors	Blown fuses, reduced capacitor life
Motors	Reduced motor life, inability to fully load motor
Fuses/breakers	False/spurious operation, damaged components
Transformers	Increased copper losses, reduced capacity
Voltage Harmonic Distortion Problems	
Transformers	Increased noise, possible insulation failure
Motors	Mechanical fatigue
Electronic loads	Misoperation

Always consider harmonic resonance, even when applying a small capacitor on a large system. High harmonic order resonance, such as the 23rd harmonic, can be especially troublesome because significant heat and interference can be created even at low magnitudes.

If you keep blowing fuses or tripping a breaker on a capacitor bank, measure the capacitor current and look for high harmonic currents

Harmonics can be “trapped” by a tuned filter trap or harmonic filter. The trap is an inductor capacitor filter which provides a low impedance path for the harmonic currents. It “traps” the harmonics between itself and the harmonic source.

Quiz. Power Factor and Harmonics

- Define power factor.
- Name some causes of a poor power factor.
- Why do you need to correct low-power factors?
- How do you correct power factors?
- What is a harmonic?
-
- What are the some of the problems that result from harmonics?
- How do you correct harmonics?

Quiz. Power Factor and Harmonics

- Define power factor. Ratio of true power (kilowatts) and apparent power (KVA). Kw/KVA. Measures how effectively current is converted into useful work.
- Name some causes of a poor power factor. Inductive loads – motors, pumps, compressors, ballasts
- Why do you need to correct low-power factors? To get more work out of existing electricity. Prevent overheating.
- How do you correct power factors? Correct with power factor capacitors
- What is a harmonic? Multiple of 60 Hz
- What are the some of the problems that result from harmonics? Overheating, blown fuses, damage components
- How do you correct harmonics? Harmonic filters

Energy Efficiency

WATER EFFICIENCY is cost-effectively delivering water services, while minimizing water and energy use.

=

Supply-Side Efficiency Measures

Water supply systems offer multiple opportunities to reduce water and energy waste directly, while better serving customer needs.

- Leak and loss reduction
- Perations and maintenance
- Pumpingsystems
- Primary/secondary wastewater treatment
- Pump systems

+

Demand-Side Efficiency Measures

Consumers

Residential

Industrial

Reducing demand by helping the consumer use water more efficiently decreases the required water supply, saving both energy and water.

- Water-efficient household appliances
- Low-flow toilets
- Low-flow showerheads
- Industrial water reuse
- Leak and water waste reduction

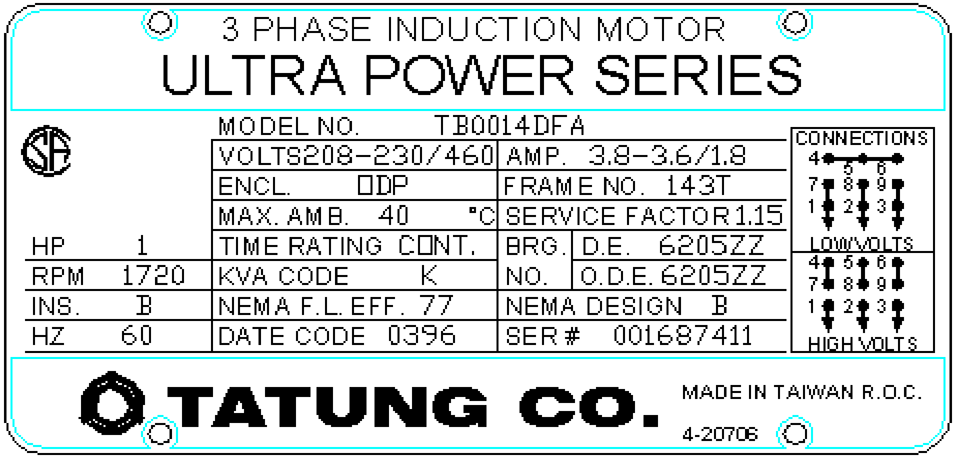
+

Comprehensive Demand-/ Supply-Side Approach Synergies

Looking at a water system comprehensively and ensuring efficiency projects are designed in tandem, creates even greater efficiency opportunites.

- Right-sizing pump systems after reducing consumer demand
- Avoiding wastewater treatment by promoting reuse and reducing demand

How to Read a Nameplate



National Electrical Manufacturers Association (NEMA) defines some basic design and dimensional parameters in NEMA Standard MG 1.

* Manufacturer's type and frame designation
* Horsepower output.
* Time rating.
* Maximum ambient temperature for which motor is designed.
* Insulation system designation.
* RPM at rated load.
* Frequency.
* Number of phases.
* Rated load current.
* Voltage.
* Code letter for locked rotor kVA. (MG 1-10.37.2)
* Design letter for medium motors.
* NEMA nominal efficiency when required by MG 1- 12.55
* Service factor if other than 1.0.
* For motors equipped with thermal protectors, the words "thermally protected“. For motors > 1hp--equipped with over-temperature devices or systems, the words “OVER TEMP PROT –”

Quiz. Final

- Using the nameplate on the previous slide:
  - How many watts will it use?
  - What size wire do you need to feed it?
- What are conditions for an arc flash?
- Comparing an electrical circuit to a water system, what are the electrical equivalents to:
  - Water pressure
  - Flow rate amperage
  - Pipe friction
- What is the force that, applied to a conductor, causes current flow?

Final cont.

- If you have a circuit in which you know voltage (volts) and current (amps), what two additional pieces of information do you need to determine power (watts)?
- In a circuit with an apparent power of 3000 VA and a power factor of 0.8, what is the wattage?
- Why do you want a high power factor?
- Why do the utilities penalize (charge) you for a low power factor?
- What problems do harmonics cause?
- What is the danger zone (in feet) for working near power lines?

Quiz. Final

- Using the nameplate on the previous slide:
  - How many watts will it use? W=VA = 2300v*3.8a=874w. 1hp=746w
  - What size wire do you need to feed it? 14 gauge

- What are conditions for an arc flash? Anytime electricity can travel through air

- Comparing an electrical circuit to a water system, what are the electrical equivalents to:
  - Water pressure voltage
  - Flow rate amperage 1*10^18 electrons per second
  - Pipe friction resistance (ohms)

- What is the force that, applied to a conductor, causes current flow? voltage

Final cont.

- If you have a circuit in which you know voltage (volts) and current (amps), what two additional pieces of information do you need to determine power (watts)? dc or ac , power factor. w=va
- In a circuit with an apparent power of 3000 VA and a power factor of 0.8, what is the wattage? VA*PF=W. PF=KW/KVA. 3000VA*.8PF=2400W
- Why do you want a high power factor? More effective usage of electricity
- Why do the utilities penalize (charge) you for a low power factor? Supply electrons they are not getting paid for
- What problems do harmonics cause? overheating
- What is the danger zone (in feet) for working near power lines? 10 ft.

Don’t Let This Be You