

# BASIC ELECTRICITY



Scott  
Fausneaucht



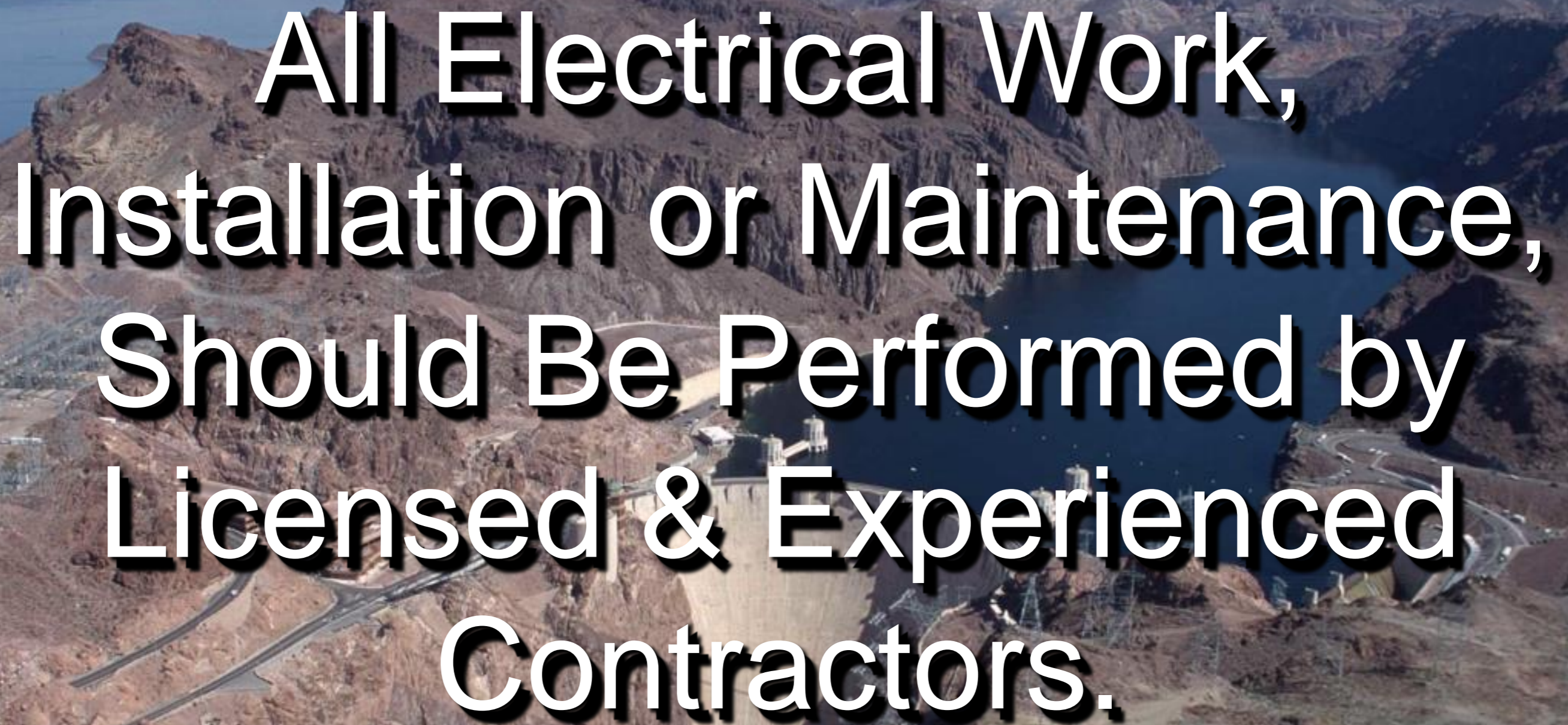
# What We Will Learn:

- ➔ Definition of Electricity
- ➔ Electrical Fundamentals
- ➔ Generation & Transmission
- ➔ Transformers
- ➔ Fuses & Circuit Breakers
- ➔ Motors
- ➔ Motor Controls
- ➔ Safety

# What This Session is Not:

- ➔ Electrical License Preparation.
- ➔ No Apprentice or Journeyman cards will be issued.



An aerial photograph of a large concrete dam and power plant situated in a deep, rugged canyon. The dam is a massive structure with a wide spillway. Below the dam, there are several large industrial buildings, likely part of the power plant. The surrounding landscape is arid and rocky, with a winding road visible on the left. In the background, a large body of water is visible, and the canyon walls rise steeply. The sky is clear and blue.

**All Electrical Work,  
Installation or Maintenance,  
Should Be Performed by  
Licensed & Experienced  
Contractors.**

# Definition - Electricity

e·lec·tric·i·ty

a form of energy resulting from the existence of charged particles, either statically as an accumulation of a charge or dynamically as a current.

# Electrical Energy

**Electrical Energy is Kinetic Energy**

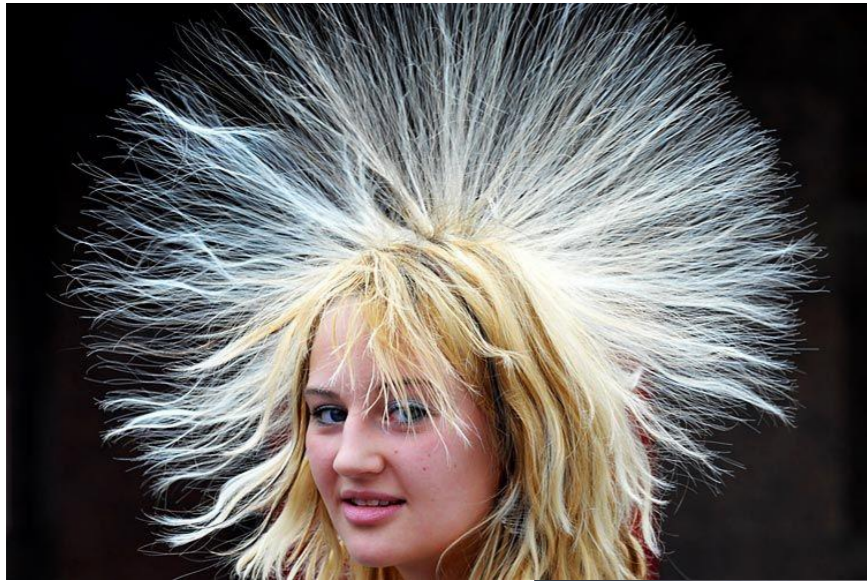
*“The Energy Possessed Due To Motion”.*

Moving wind and moving water are two forms of Kinetic Energy.

# Electrical Energy

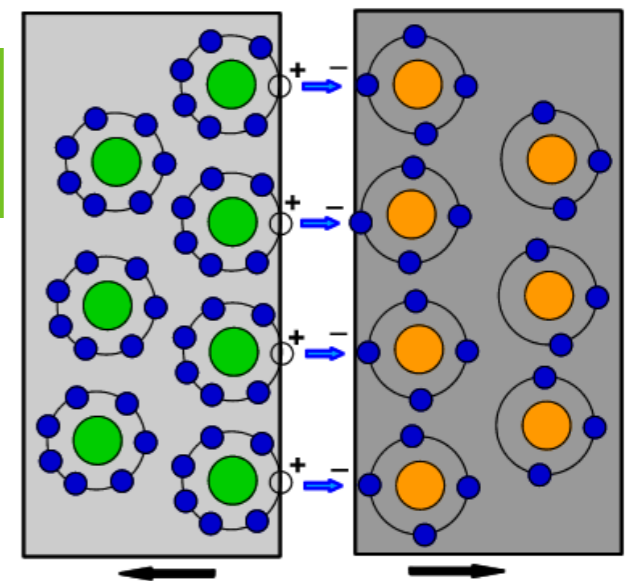
## Two Forms of Electrical Energy

- *Static*
- *Dynamic*

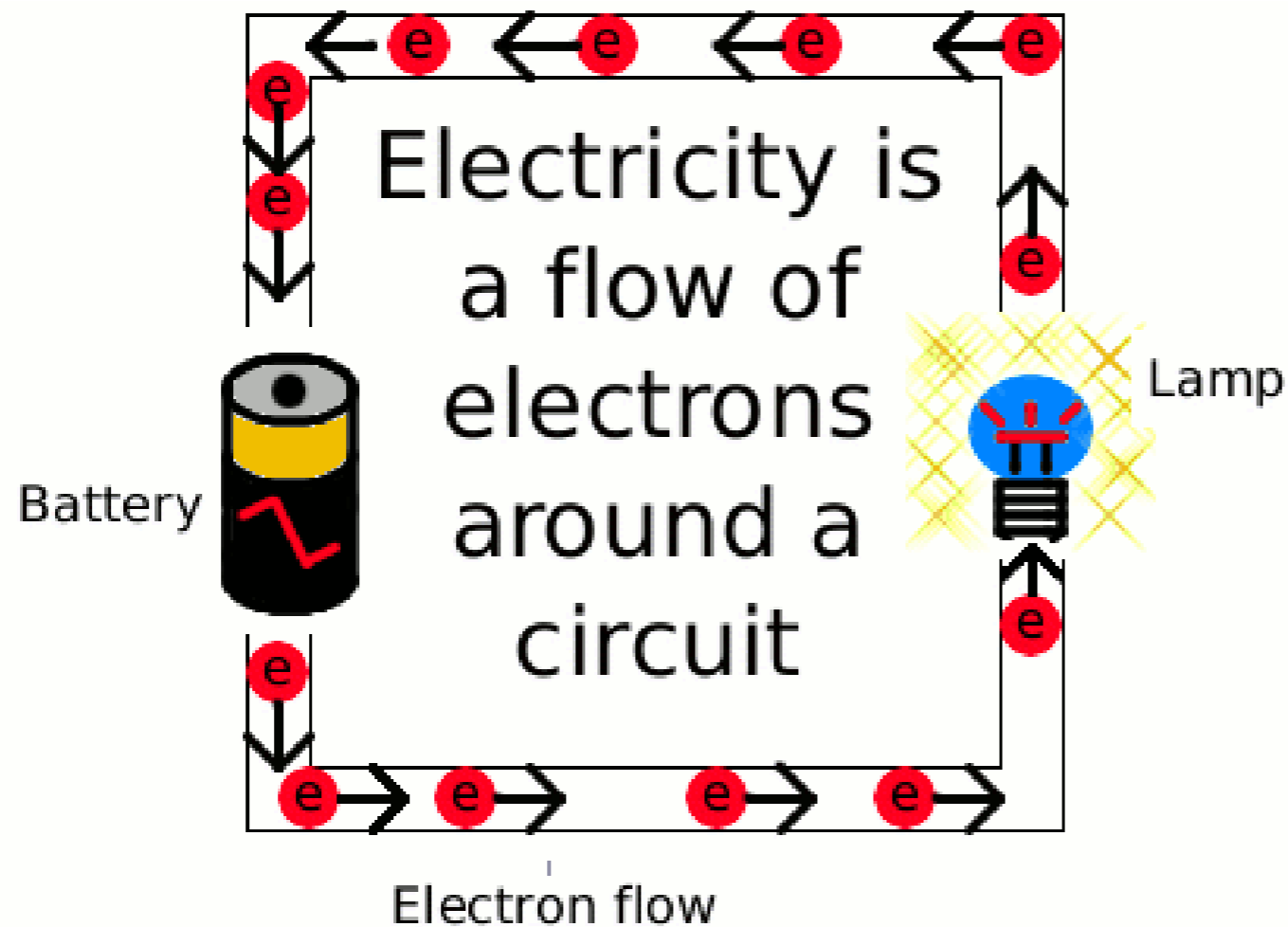


Static electricity is an imbalance of electric charges within or on the surface of a material. The charge remains until it is able to move away by means of an electric current or electrical discharge. Static electricity is named in contrast with current electricity, which flows through wires or other conductors and transmits energy.

# Static Electricity







Dynamic electricity is the flow of electric charges through a conductor; in other words, an electric current.

## Dynamic Electricity

Dynamic electricity is usable to us as the conveyance of generated energy. In a way, we are connecting directly to the power's source to perform our desired work.



# Dynamic Electricity

The Kinetic Energy of falling water is transferred thru electrical current to perform work.



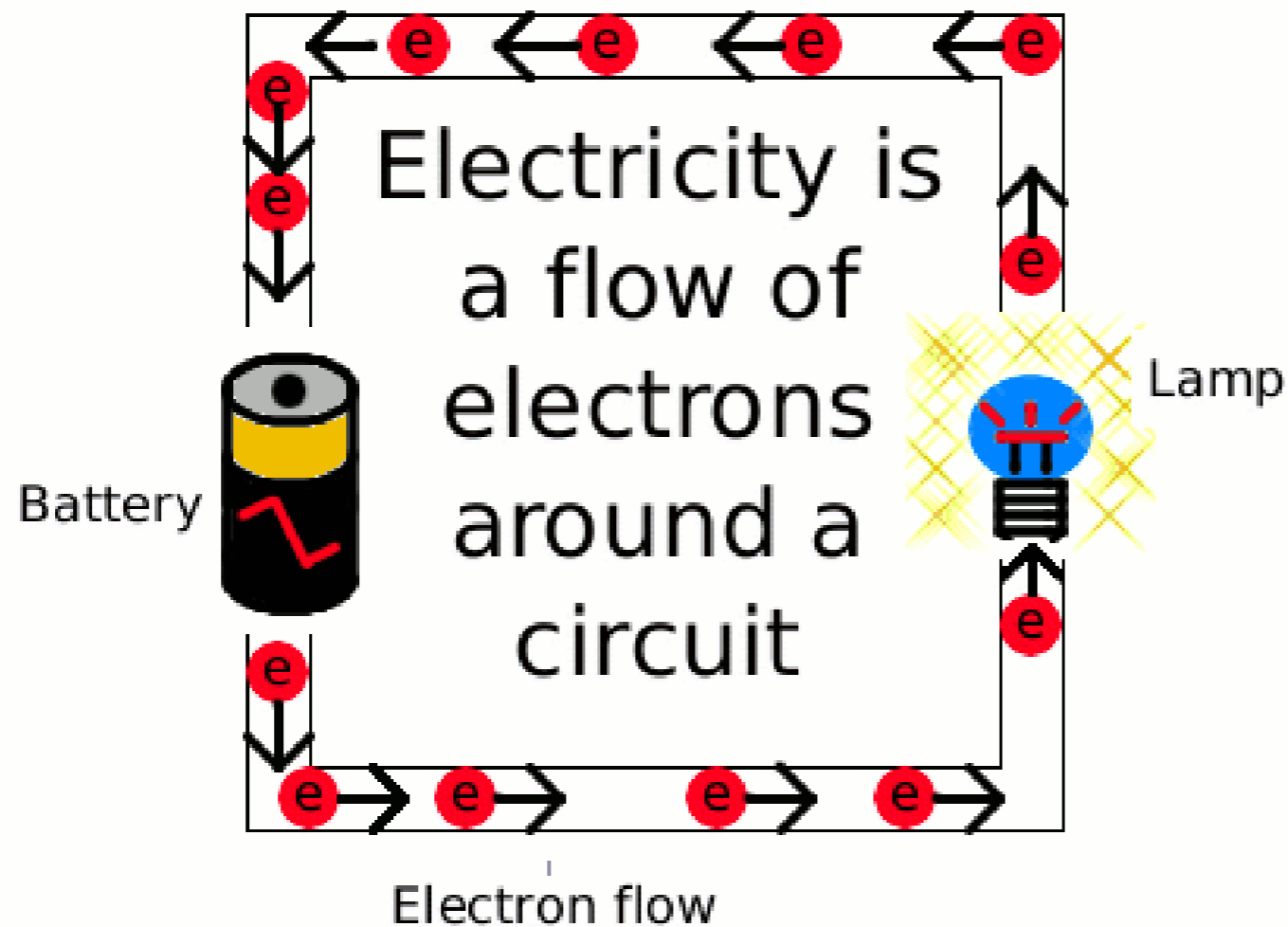
## Dynamic Electricity

The Kinetic Energy of wind is transferred thru electrical current to perform work.



## Dynamic Electricity

The Kinetic Energy of Steam Pressure is transferred thru electrical current to perform work.



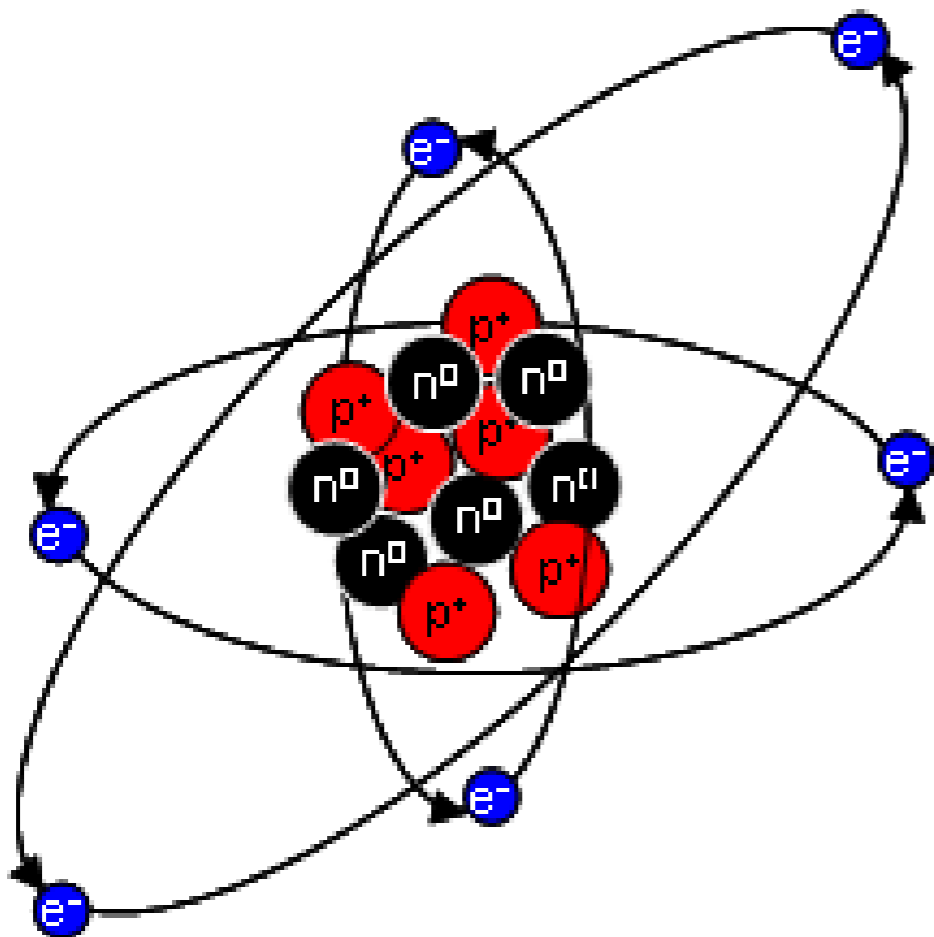
Dynamic electricity is the flow of electric charges through a conductor; in other words, an electric current.

## Dynamic Electricity

Dynamic electricity is usable to us as the conveyance of generated energy. In a way, we are connecting directly to the power's source to perform our desired work.

# Electrical Fundamentals

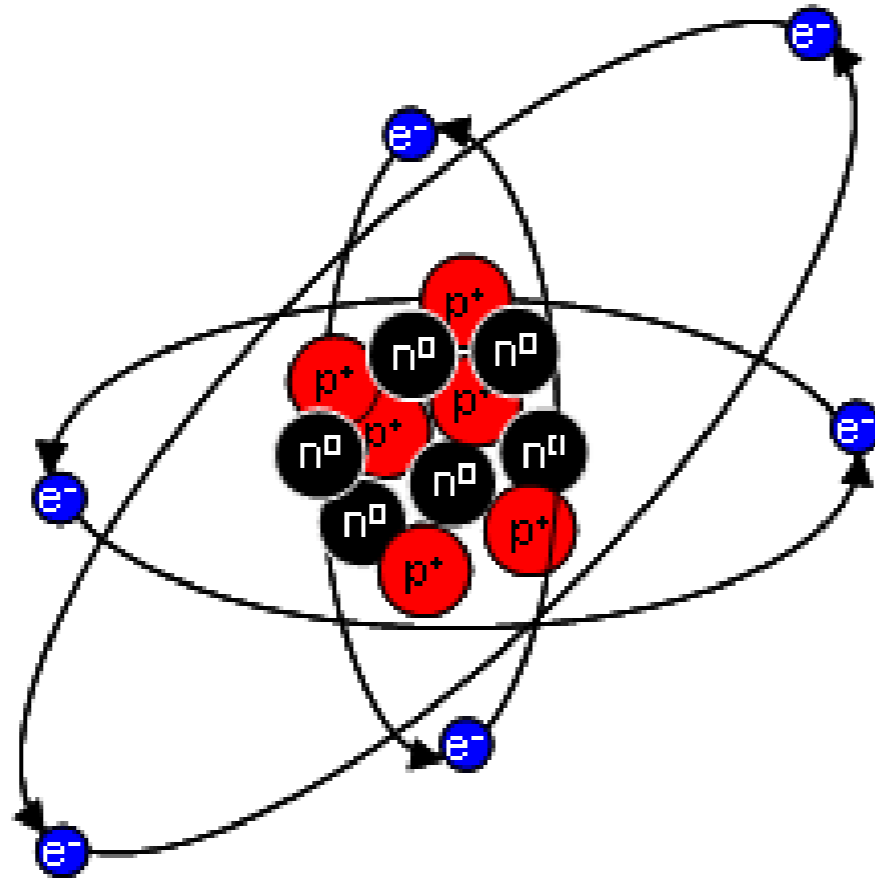
Basic electrical fundamentals begin with the atom.



Protons – Positively Charged

Neutrons – Neutral

Electrons – Negatively Charged

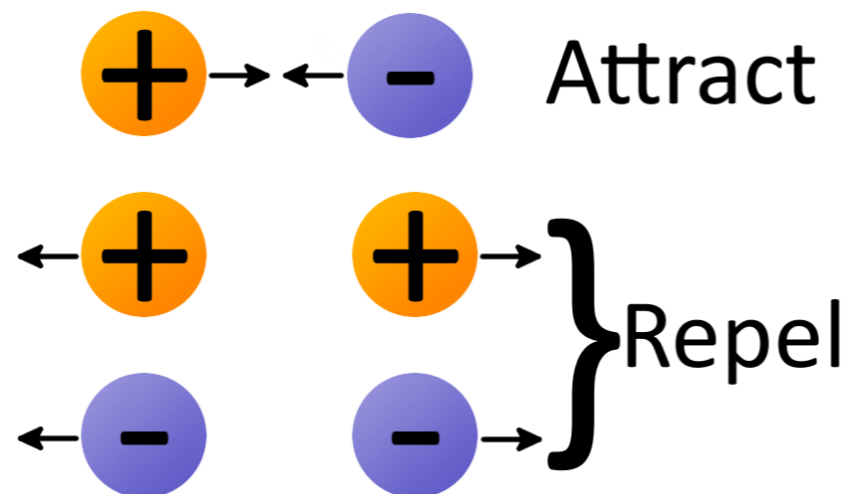
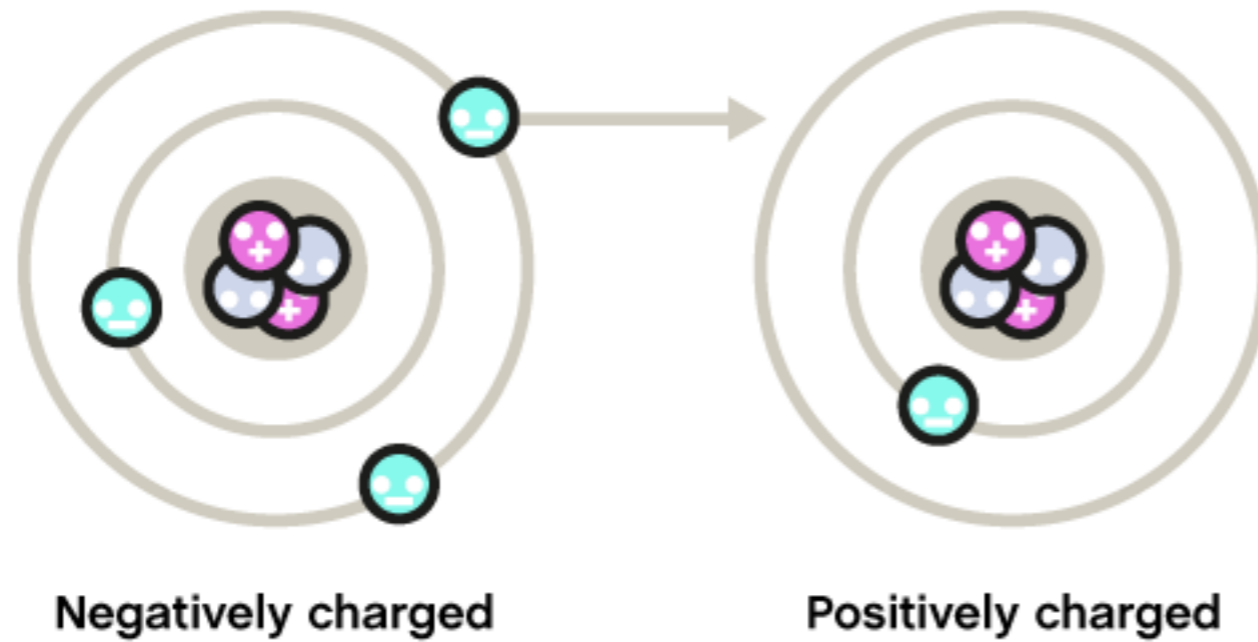


Protons = Electrons – the Atom is Neutral.

Protons > Electrons – the Atom is Positively Charged

Electrons > Protons – the Atom is Negatively Charged

# Atomic Charges



## Atomic Charges

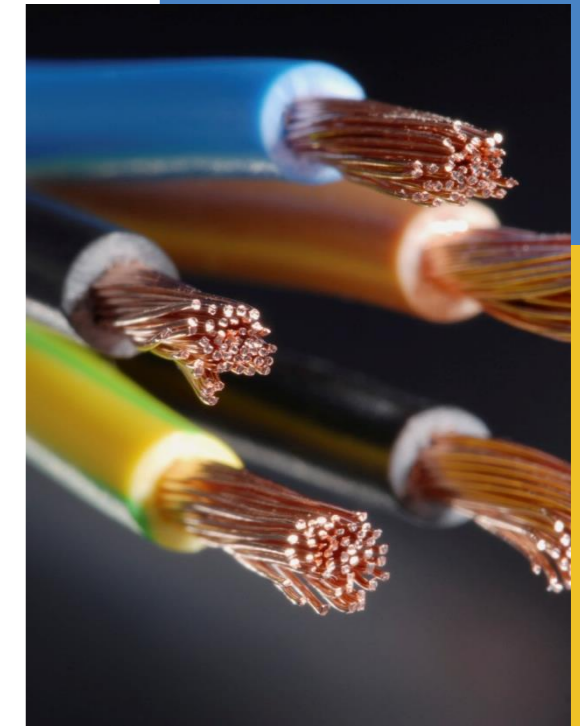
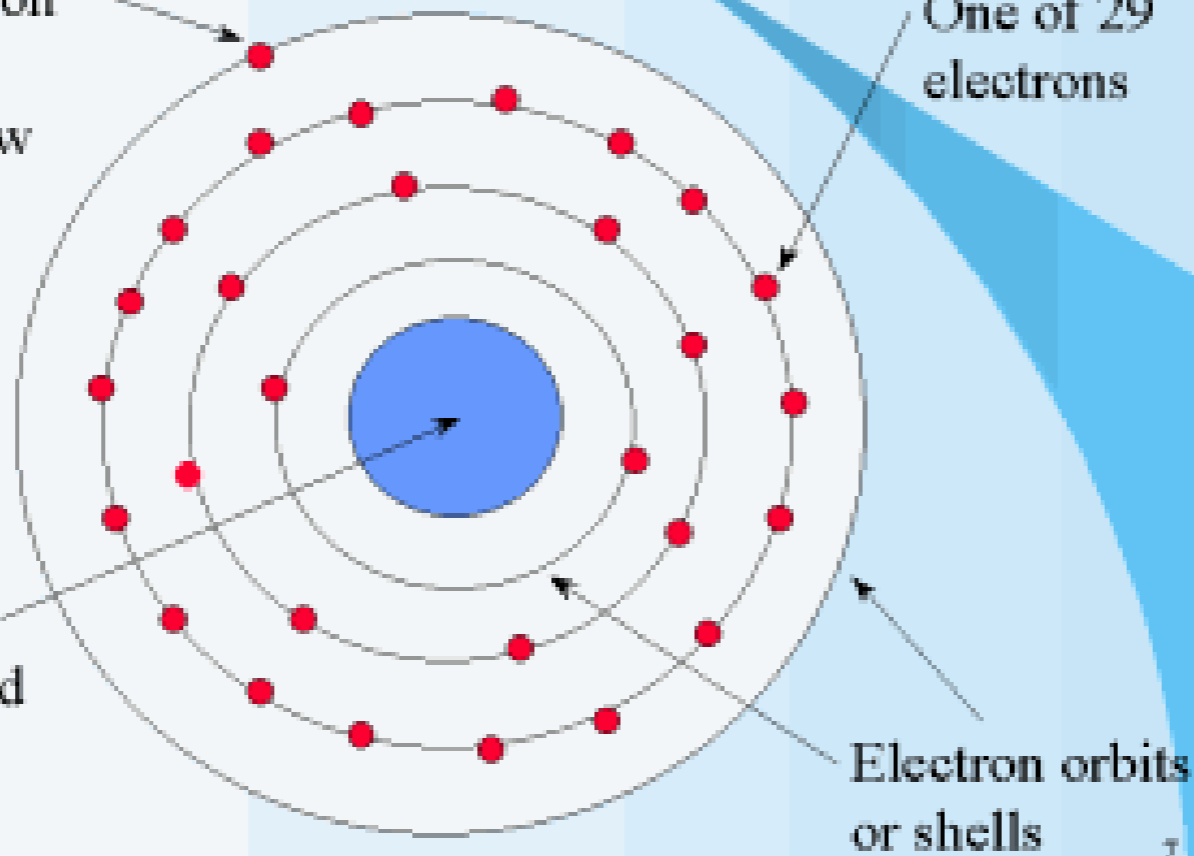
Electrostatic force (also called Coulomb's law) is a force that operates between charges. It states that charges of the same type repel each other, while charges of opposite types are attracted together.



# Structure of a Copper Atom

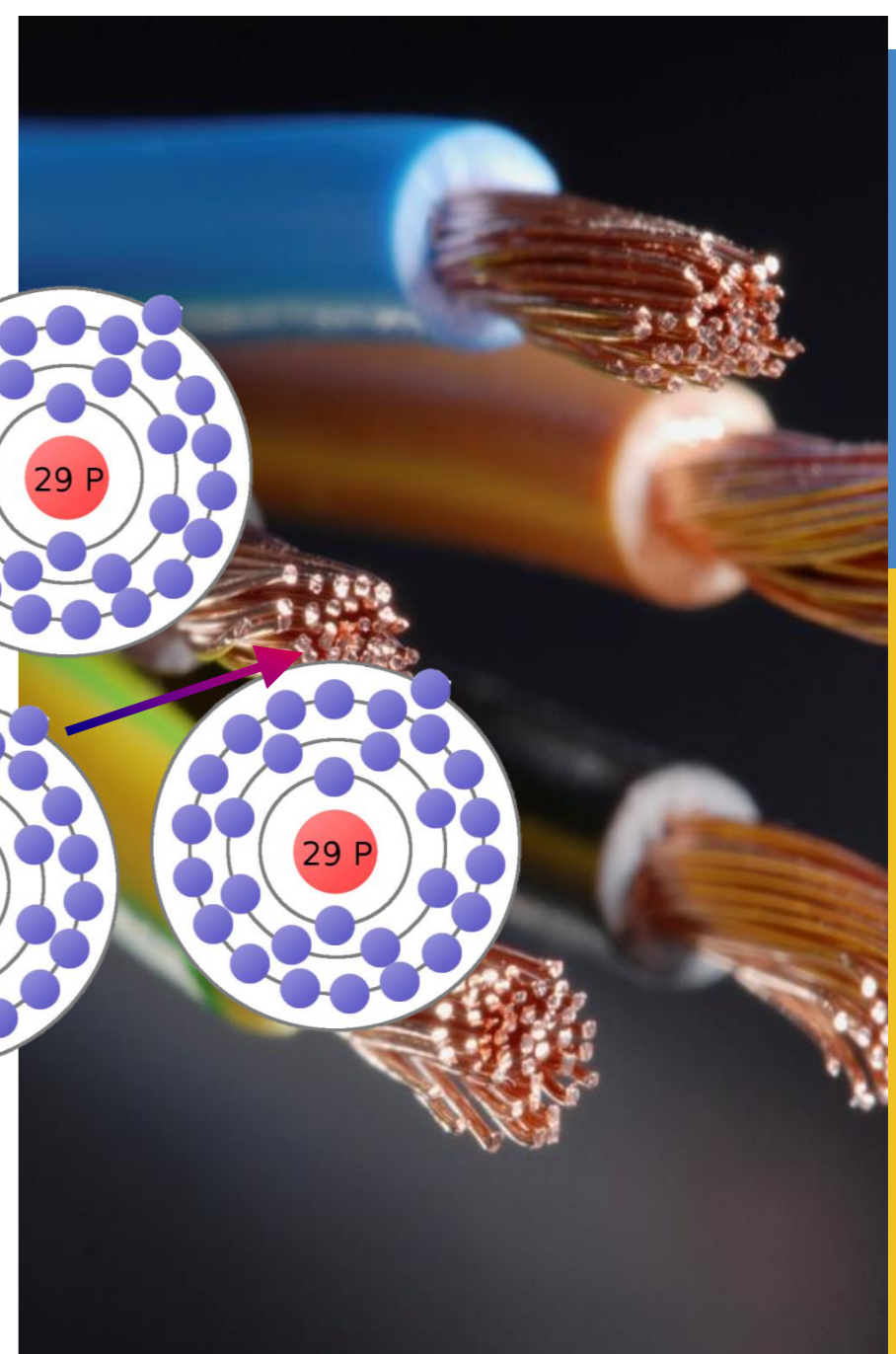
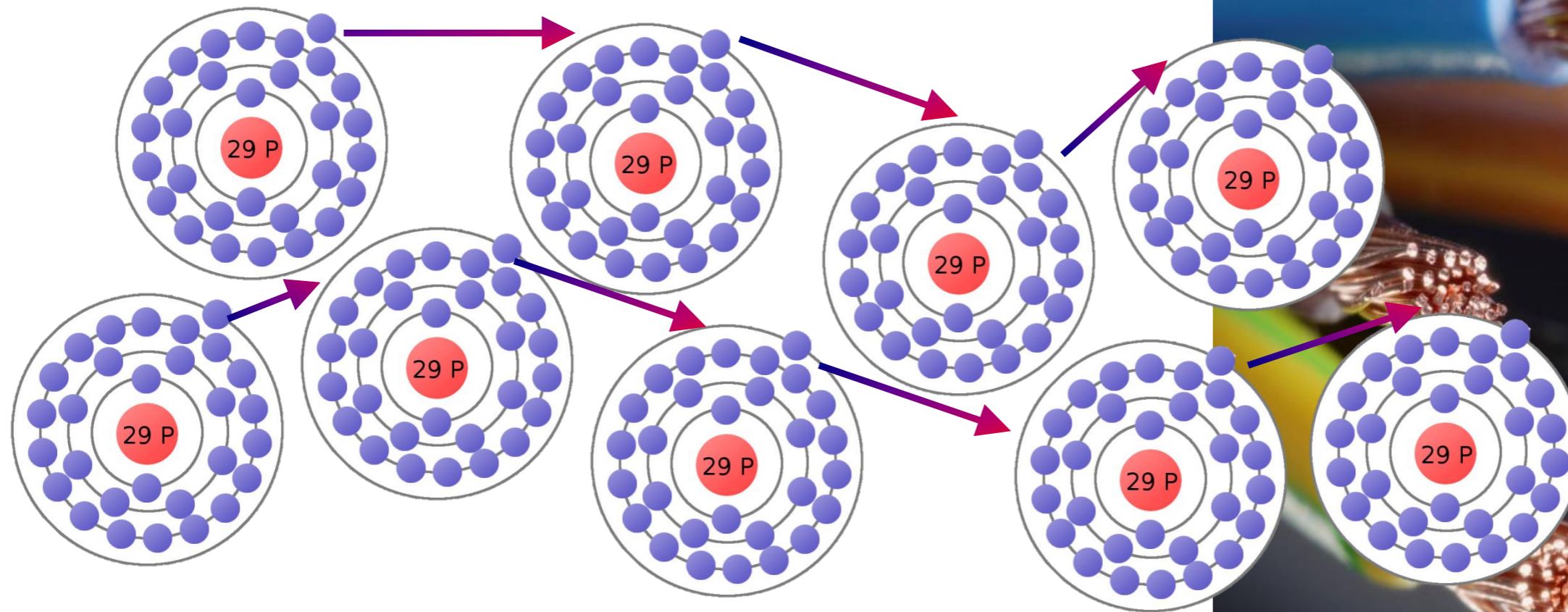
Valence electron  
available  
for current flow

Nucleus with  
29 protons and  
neutrons



## Conductors - Copper Atom

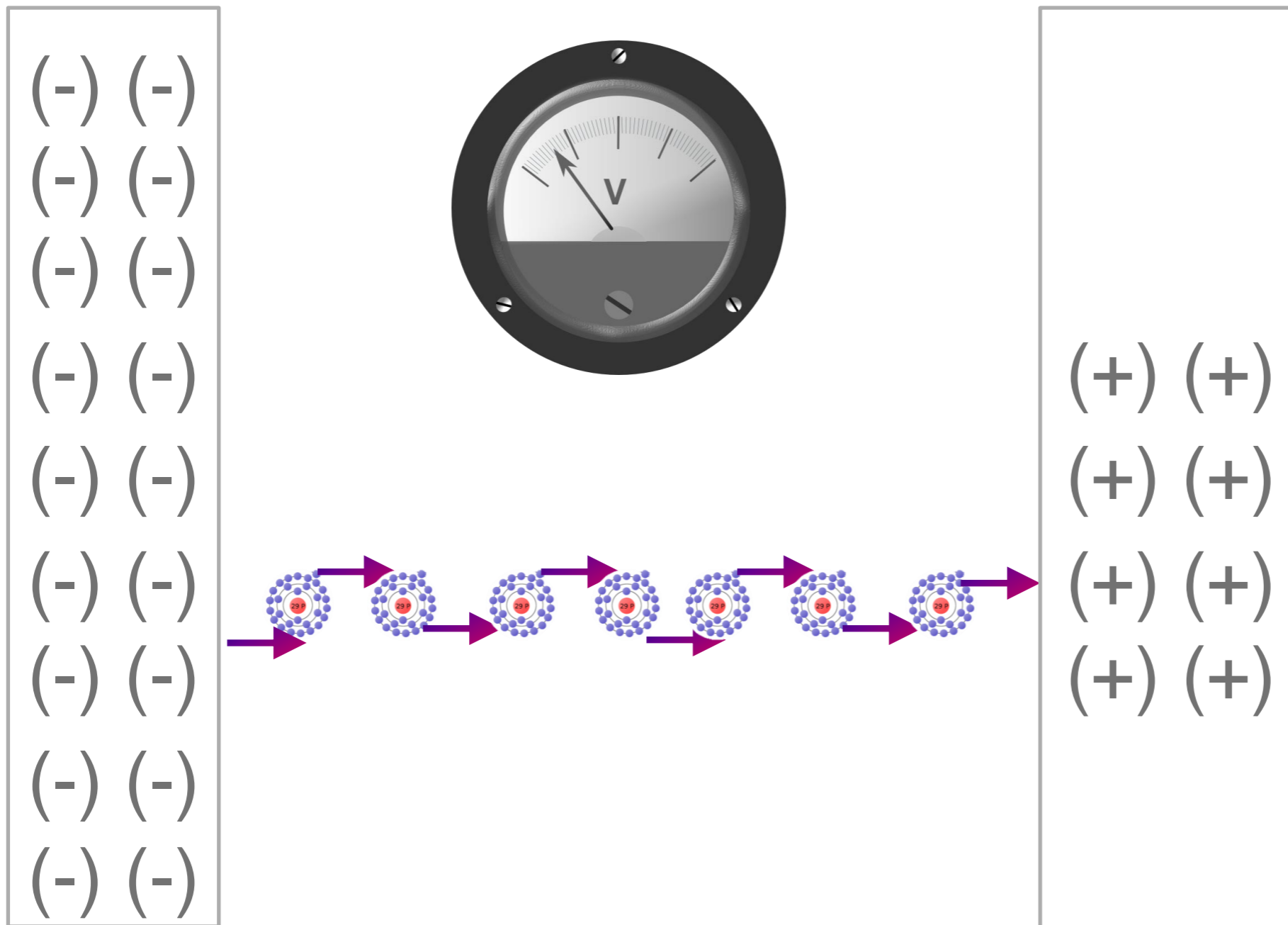
- Conductive Bands (Shells)
- Valance Band



This flow is CURRENT. Flow will continue until Equilibrium, or Balance, is reached.

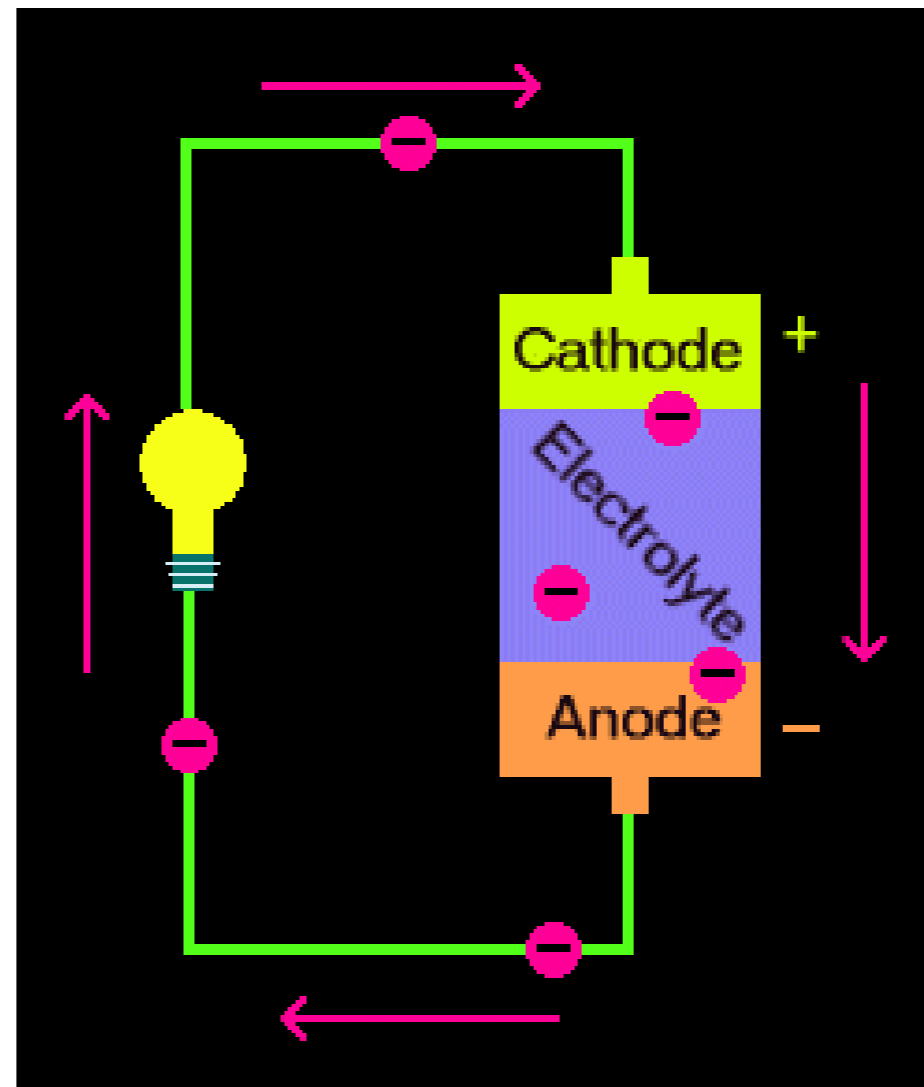
## Electron Travel - Amperes

Current is measured in Amperes, or Amps, or the symbol (I).



# Different Potentials - Voltage

Electrical Potential is the ability to provide free electrons.  
This difference is measured in Volts (V)

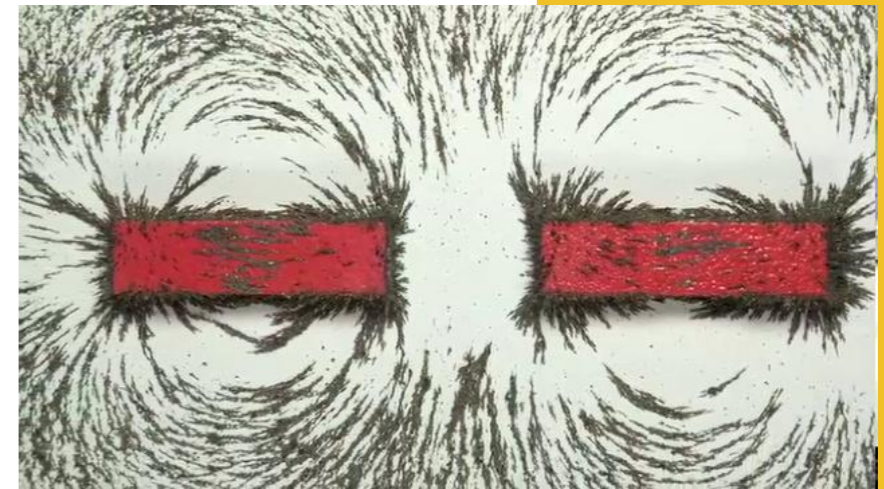
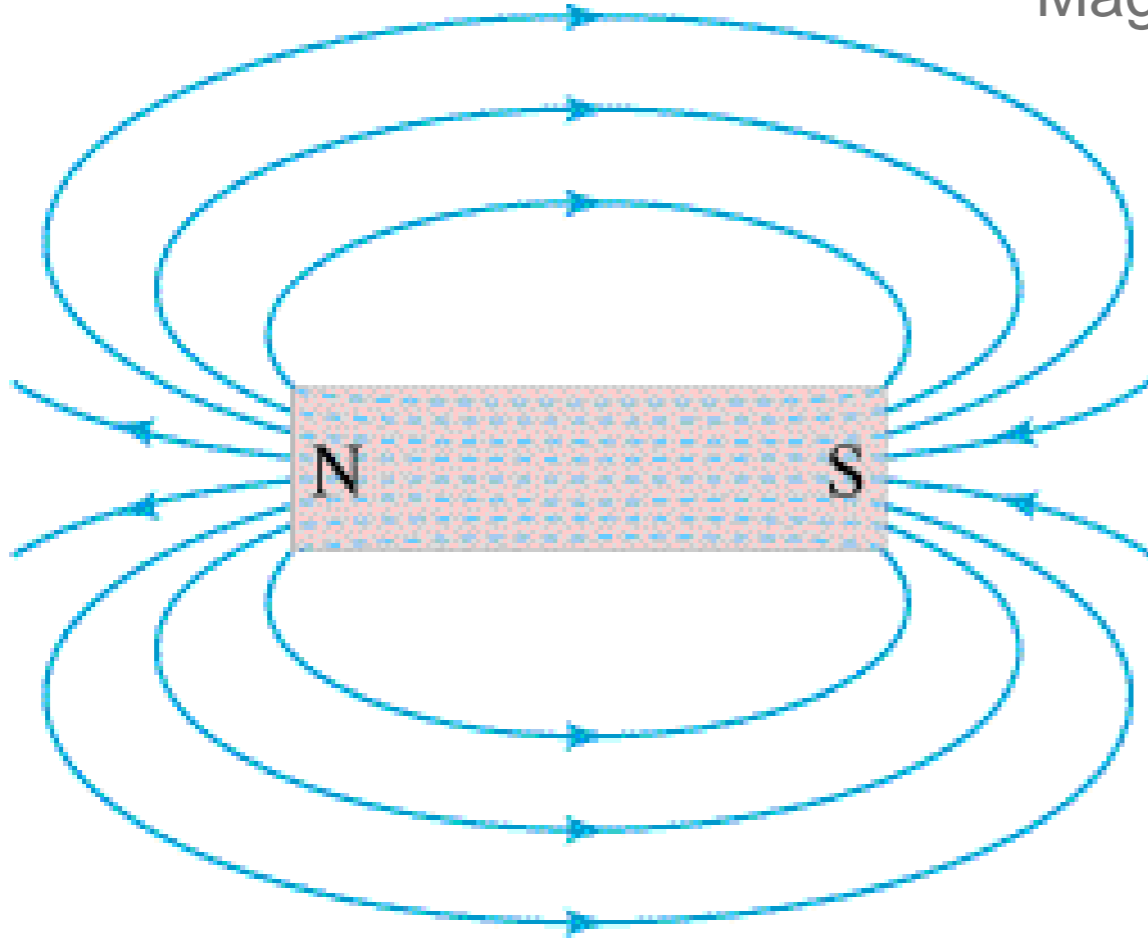


The chemical reactions in the battery causes a build up of electrons at the anode (-). This results in an electrical difference between the anode and the cathode.

## Battery Power

That difference, or Potential, will cause the Current to flow when a Conductor is placed between the anode and cathode.

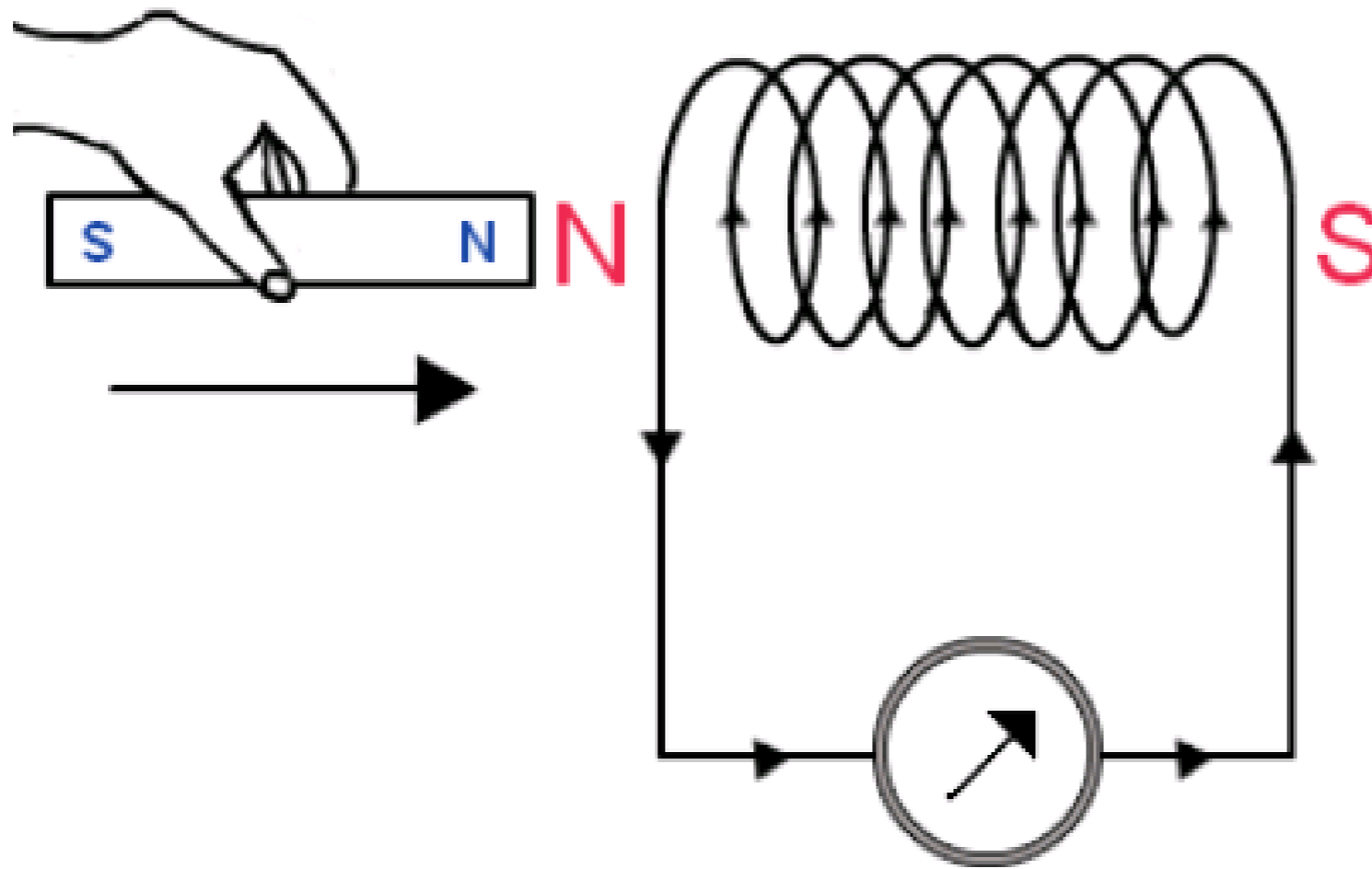
## Magnetic Lines of Force



Magnetism is a form of energy, and exerts a force.

# Magnetism

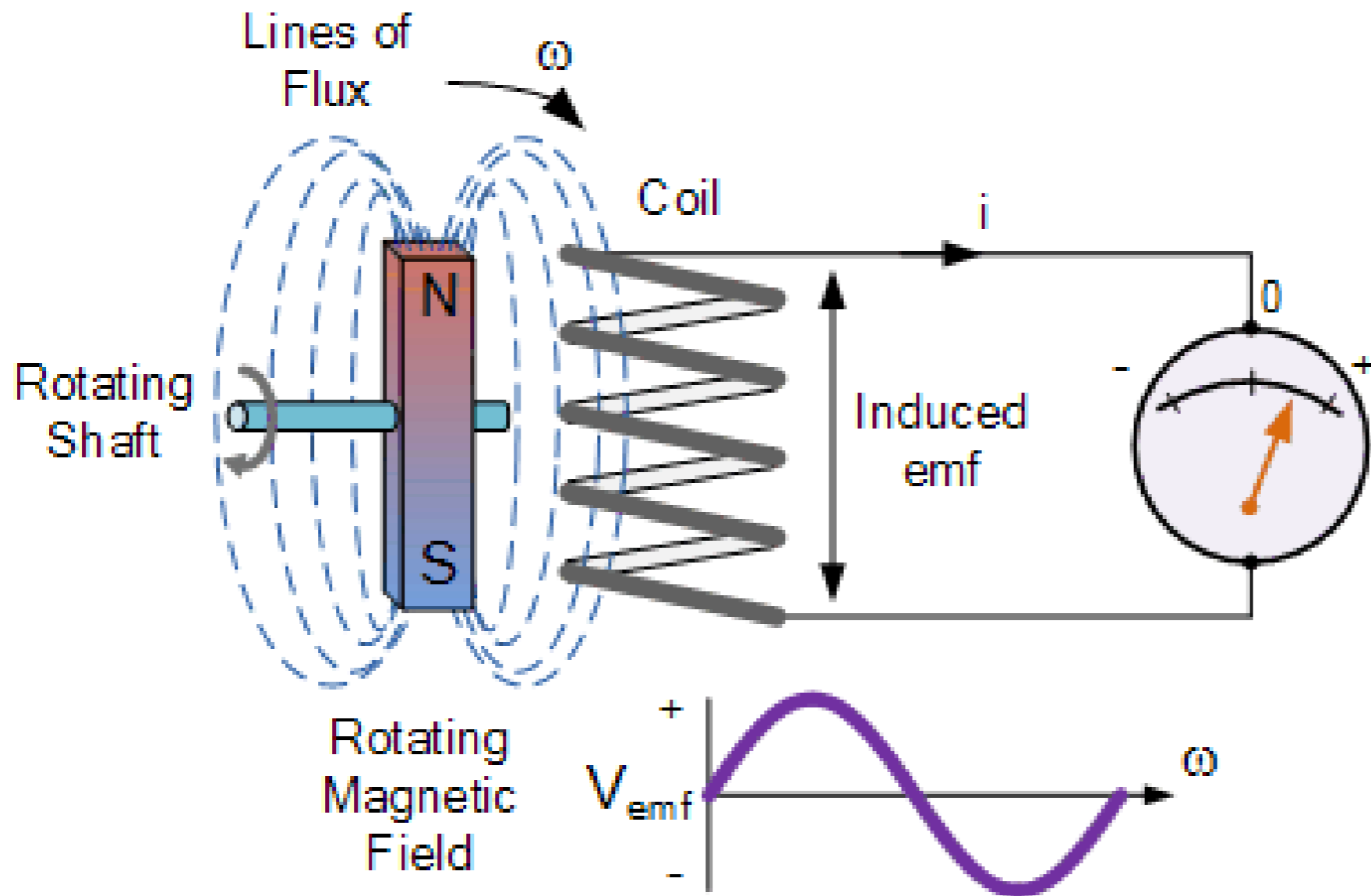
We can use the phenomena of magnetic lines of force, or the *Magnetic Field*, to begin the flow of electrons.



Electromagnetic Induction - Electromotive Force -

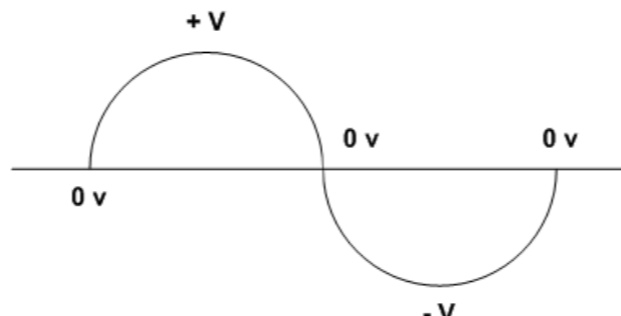
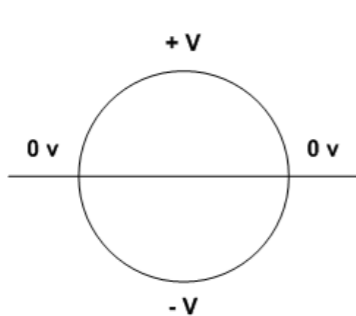
## Faraday's Law of Induction

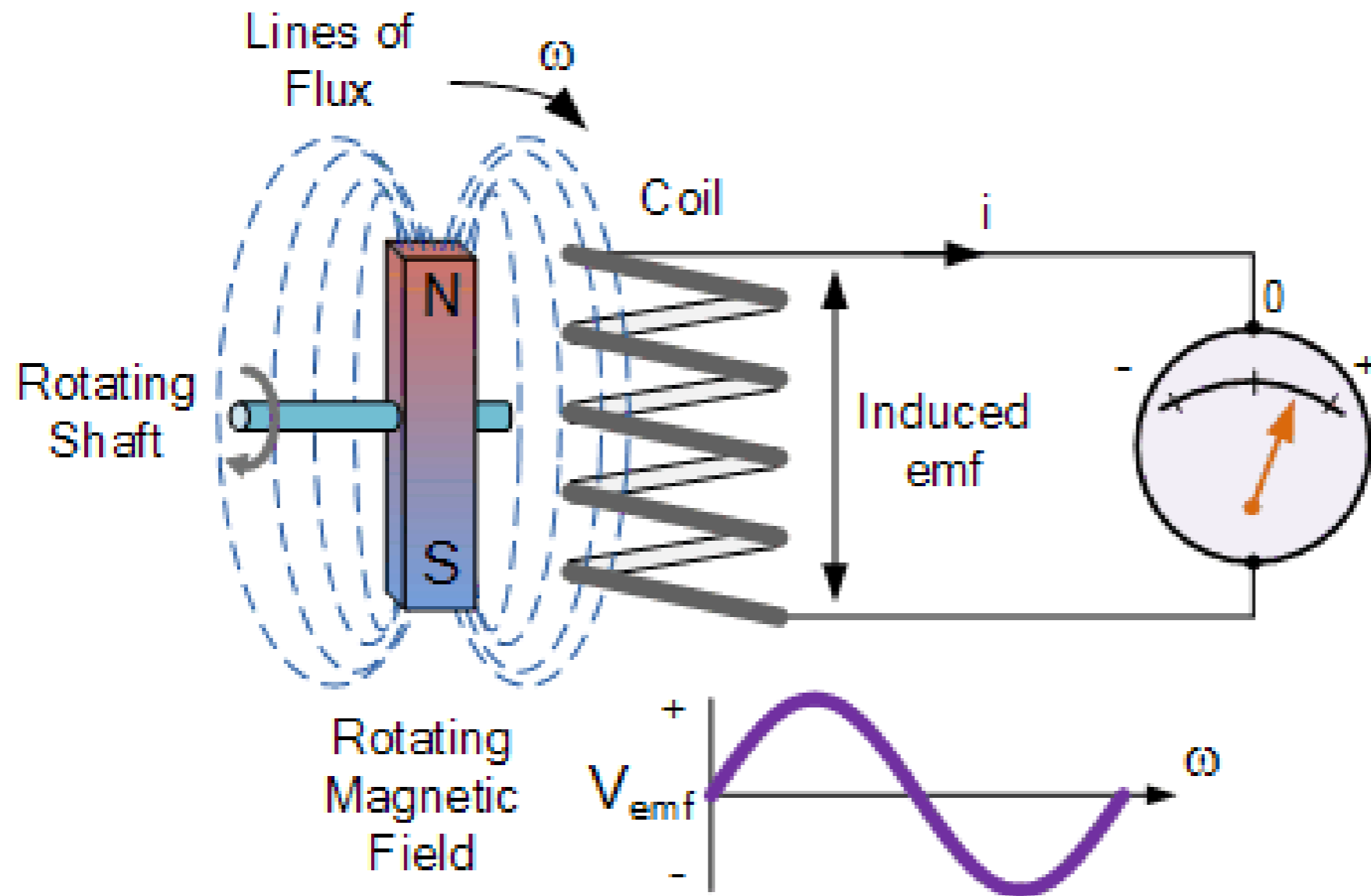
Induced voltage in a coil is proportional to the product of the loops and the rate at which the magnetic field changes within the loops.



Electromagnetic Induction - Electromotive Force -

# Faraday's Law of Induction





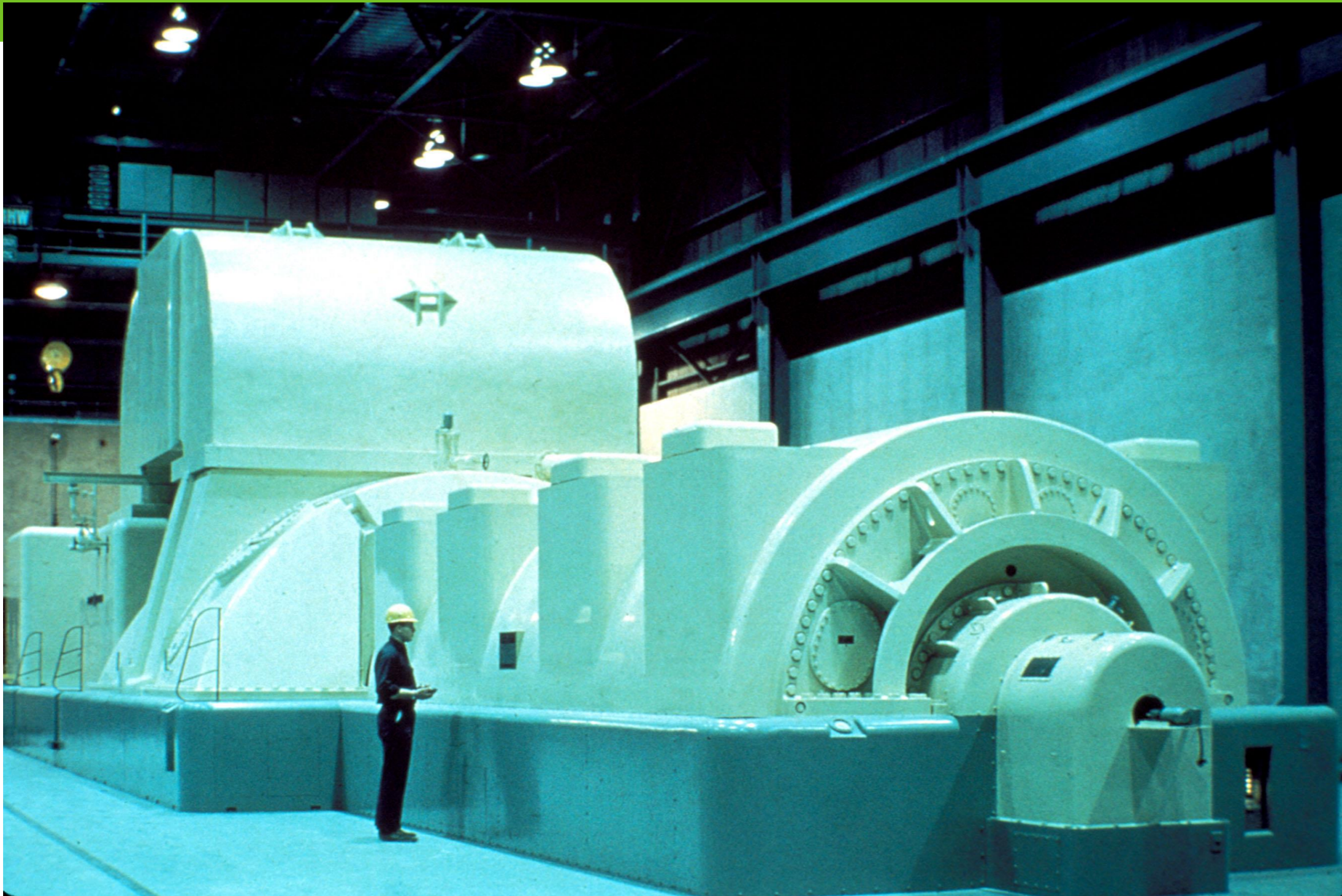
Electromagnetic Induction - Electromotive Force -

# Faraday's Law of Induction

Induced voltage in a coil is proportional to the product of the loops and the rate at which the magnetic field changes within the loops.



# Generation & Transmission

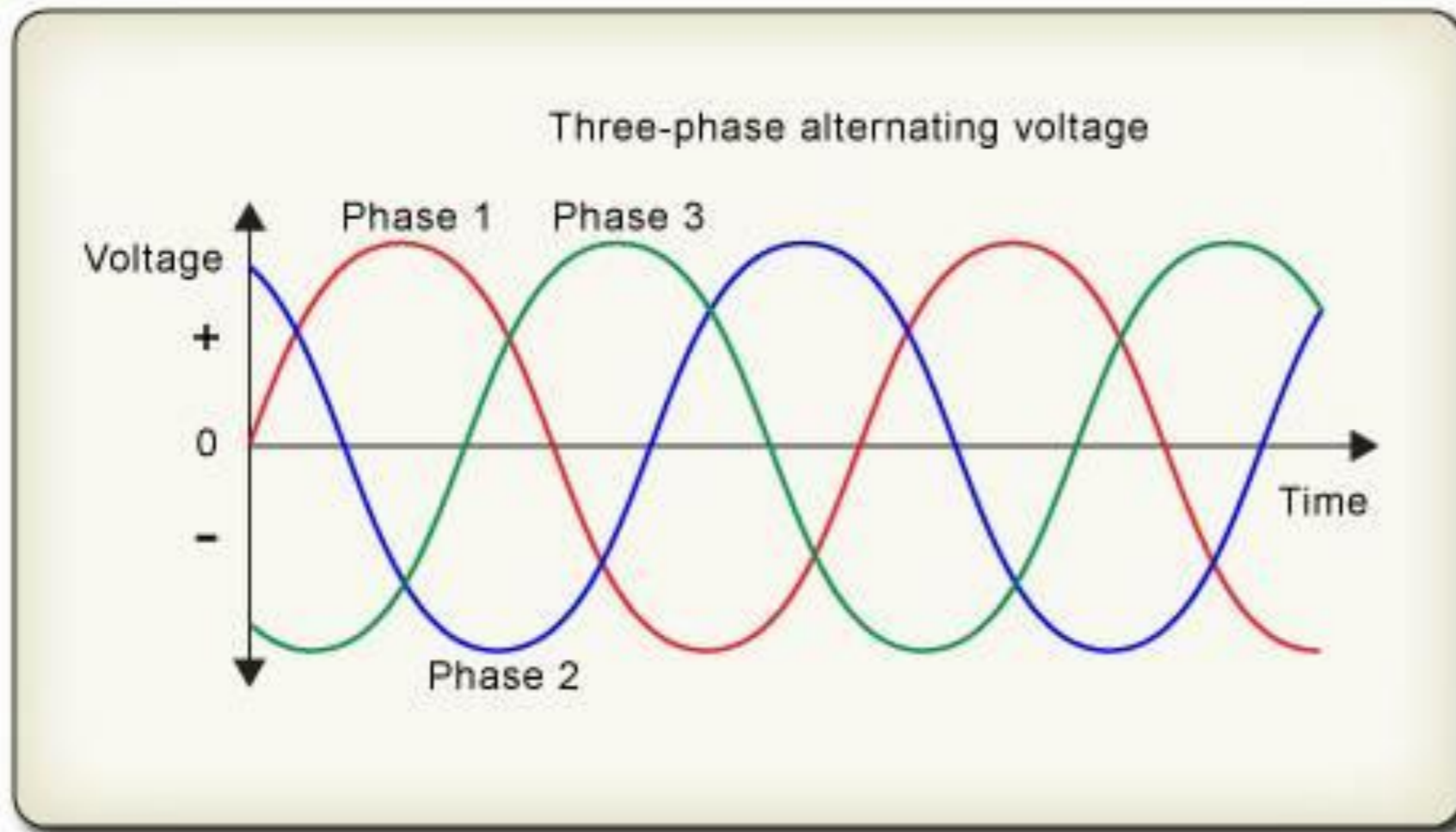




**A Generator is a machine that changes mechanical energy into electrical energy**

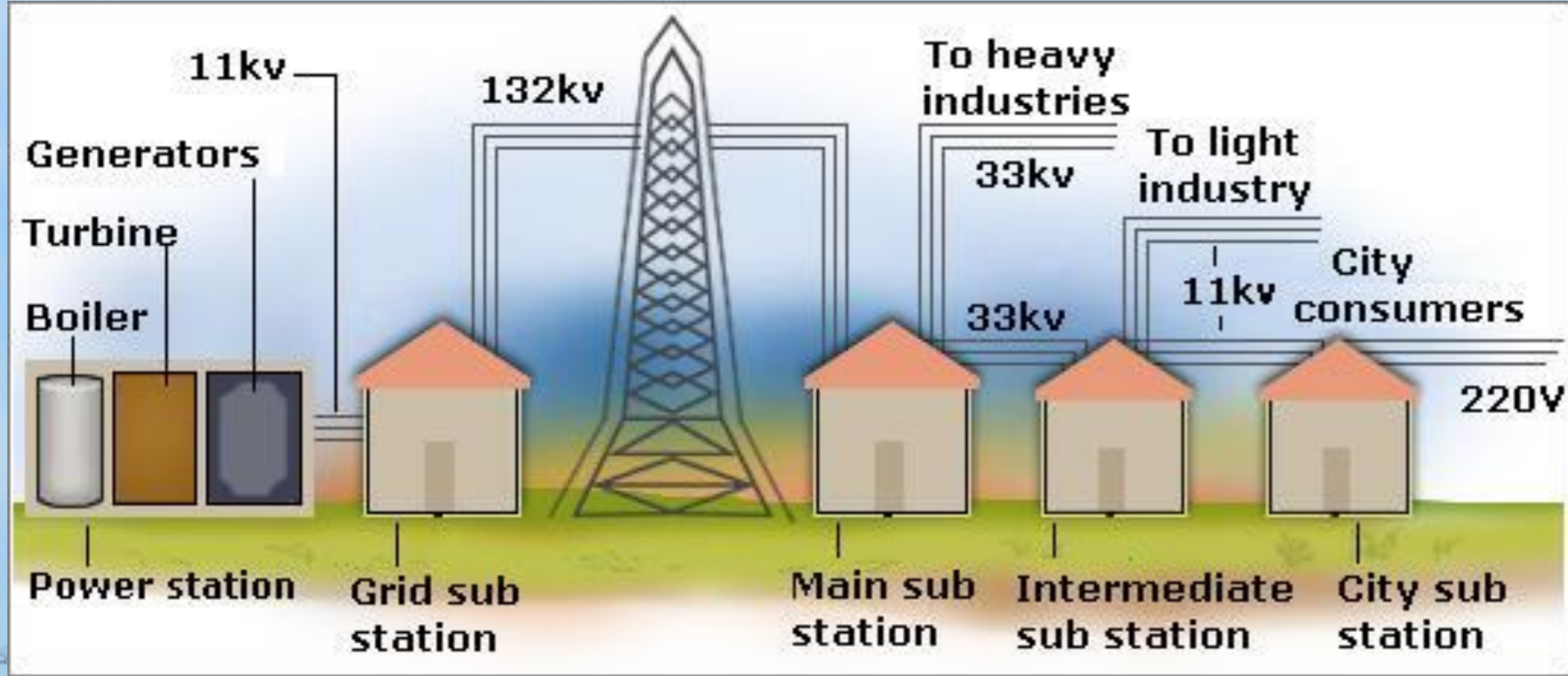
## **Generated Electrical Power**

Generators, without a rectifier, will produce AC power.  
(Alternating Current)



# Generated Electrical Power

Alternating, 3 phase generated power



# Transmission

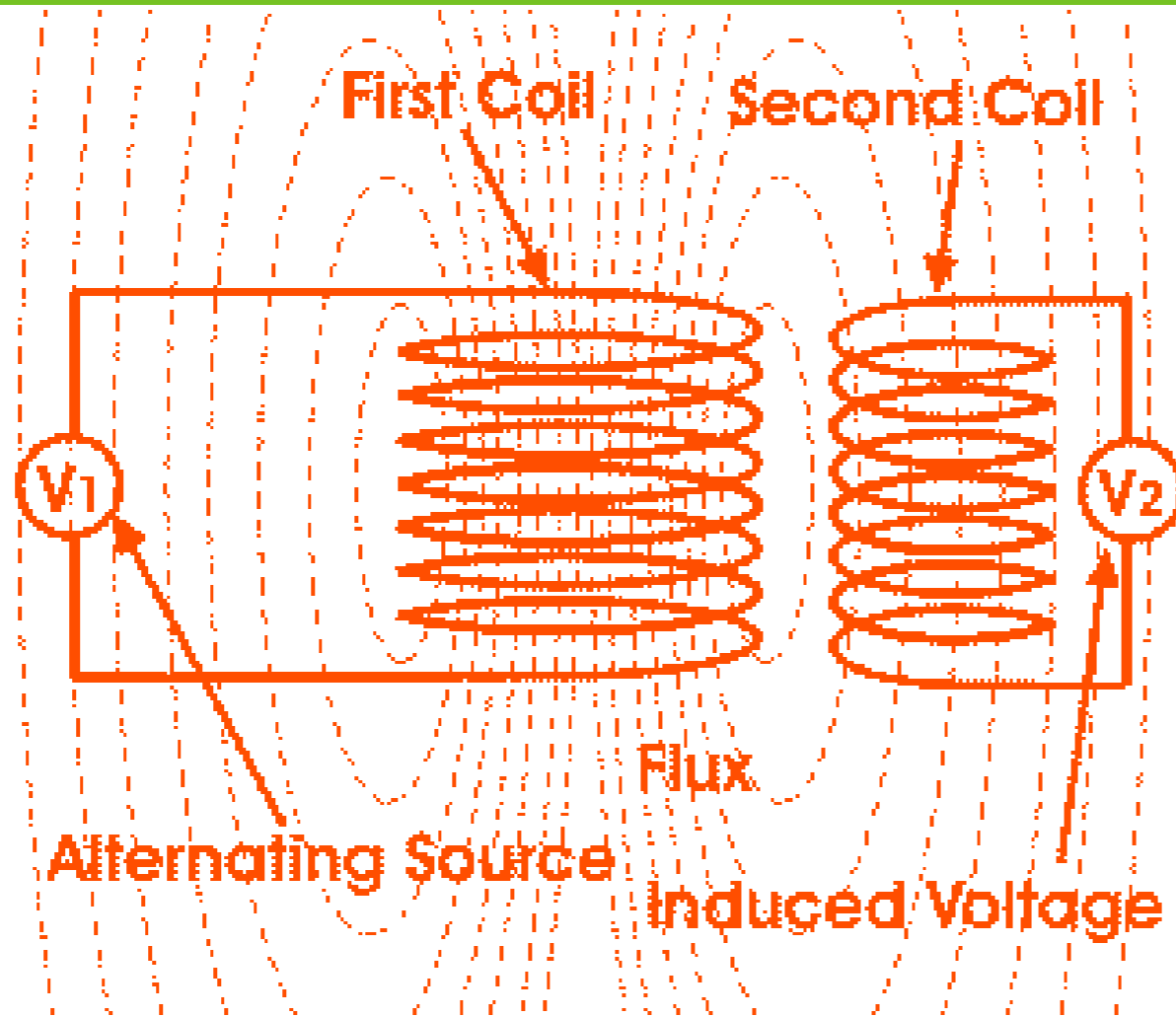


# Transformers



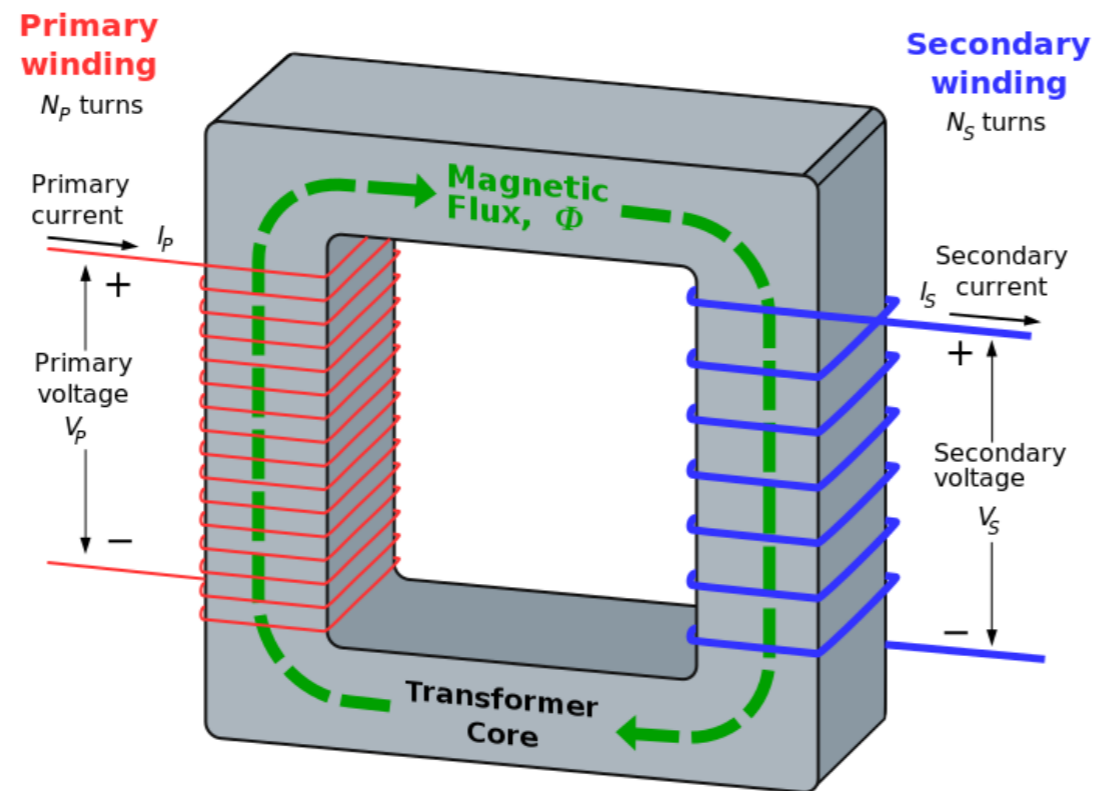
Transfers energy between two circuits through electromagnetic induction

# Transformers



Transfers energy between two circuits through electromagnetic induction

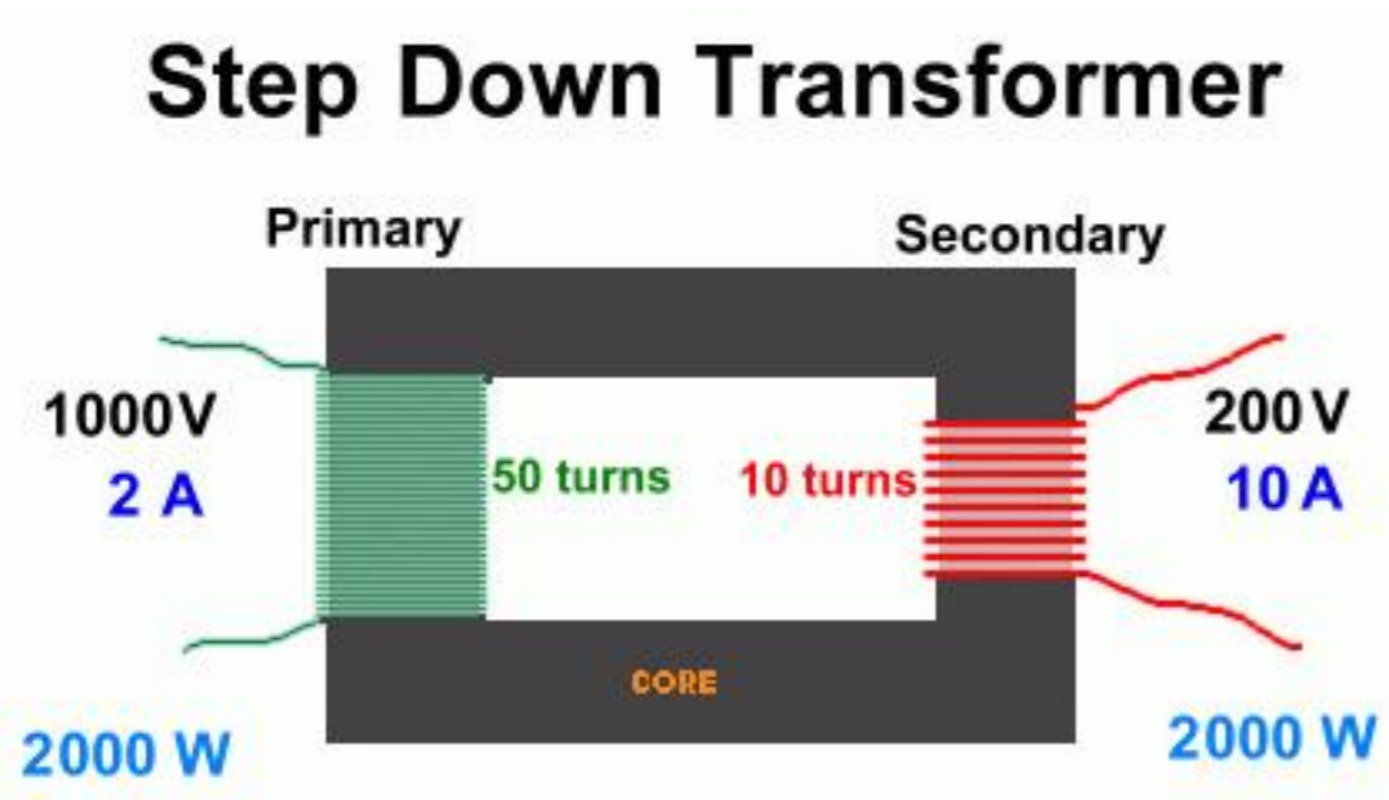
Electrical transformers are used to "transform" voltage from one level to another, usually from a higher voltage to a lower voltage. They do this by applying the principle of magnetic induction between coils to convert voltage and/or current levels.



# Transformers

Transformers work only with a varying electric current, such as alternating current (AC).

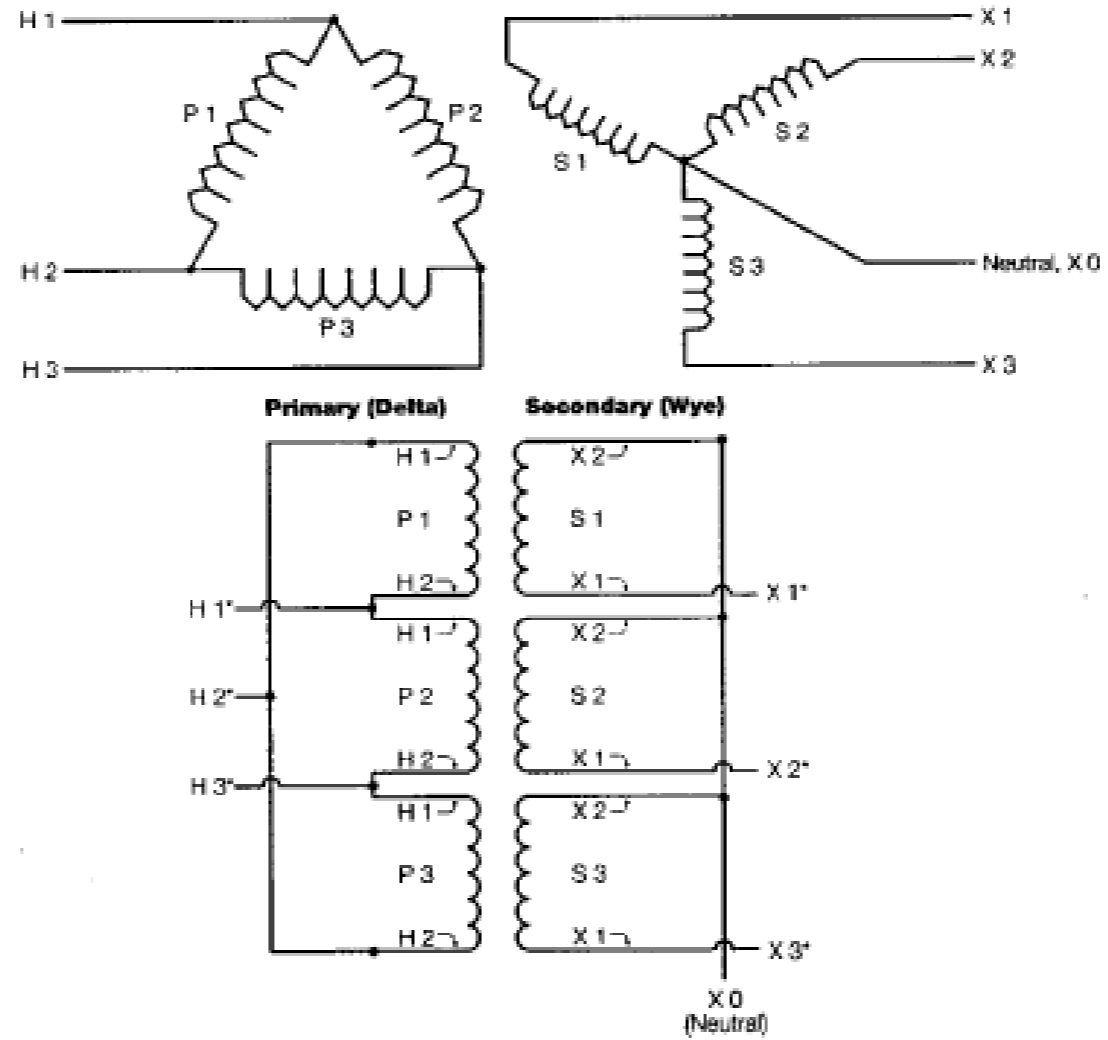
Electrical transformers are used to "transform" voltage from one level to another, usually from a higher voltage to a lower voltage. They do this by applying the principle of magnetic induction between coils to convert voltage and/or current levels.



# Transformers

Transformers work only with a varying electric current, such as alternating current (AC).

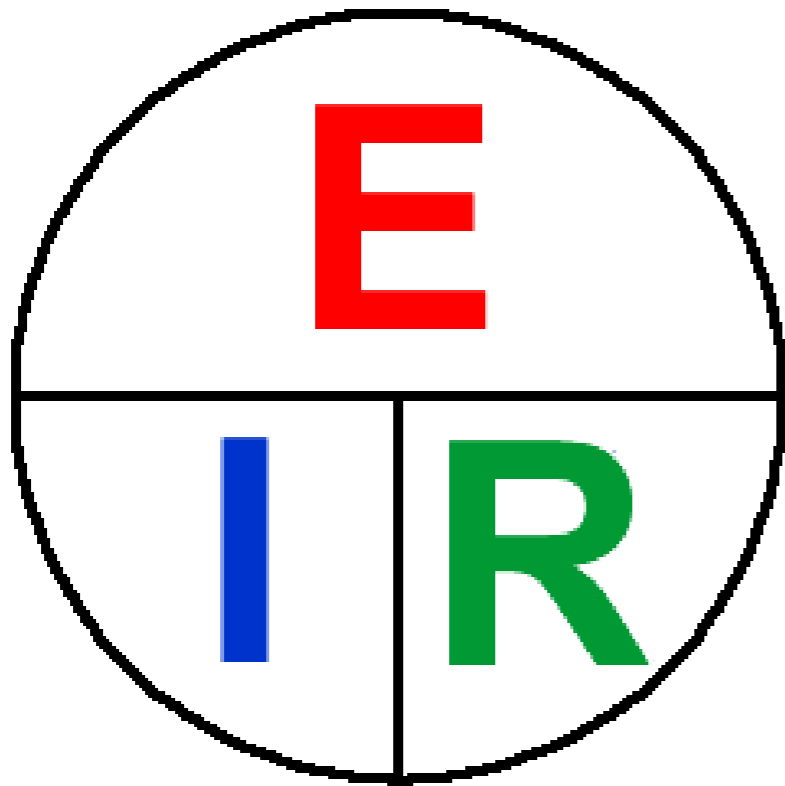




# Transformers

Three phase step down transformer – typical of a 480v to 208/120 4 wire system

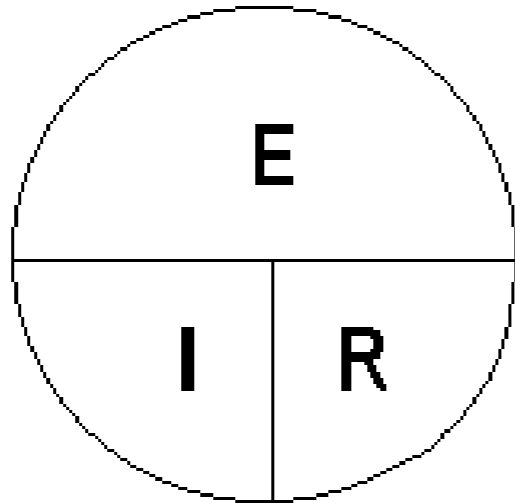
# Ohm's Law



Ohm's Law shows the relationship between

- Voltage (**E** = Electromotive Force)
- Current (**I** = Amps) and
- Resistance (**R** = Ohms)

# OHM's LAW



**E = Electromotive Force**  
measured in VOLTS

**I = Current**  
measured in AMPS

**R = Resistance**  
measured in OHM's

$$E = I \times R \quad I = E \div R \quad R = E \div I$$

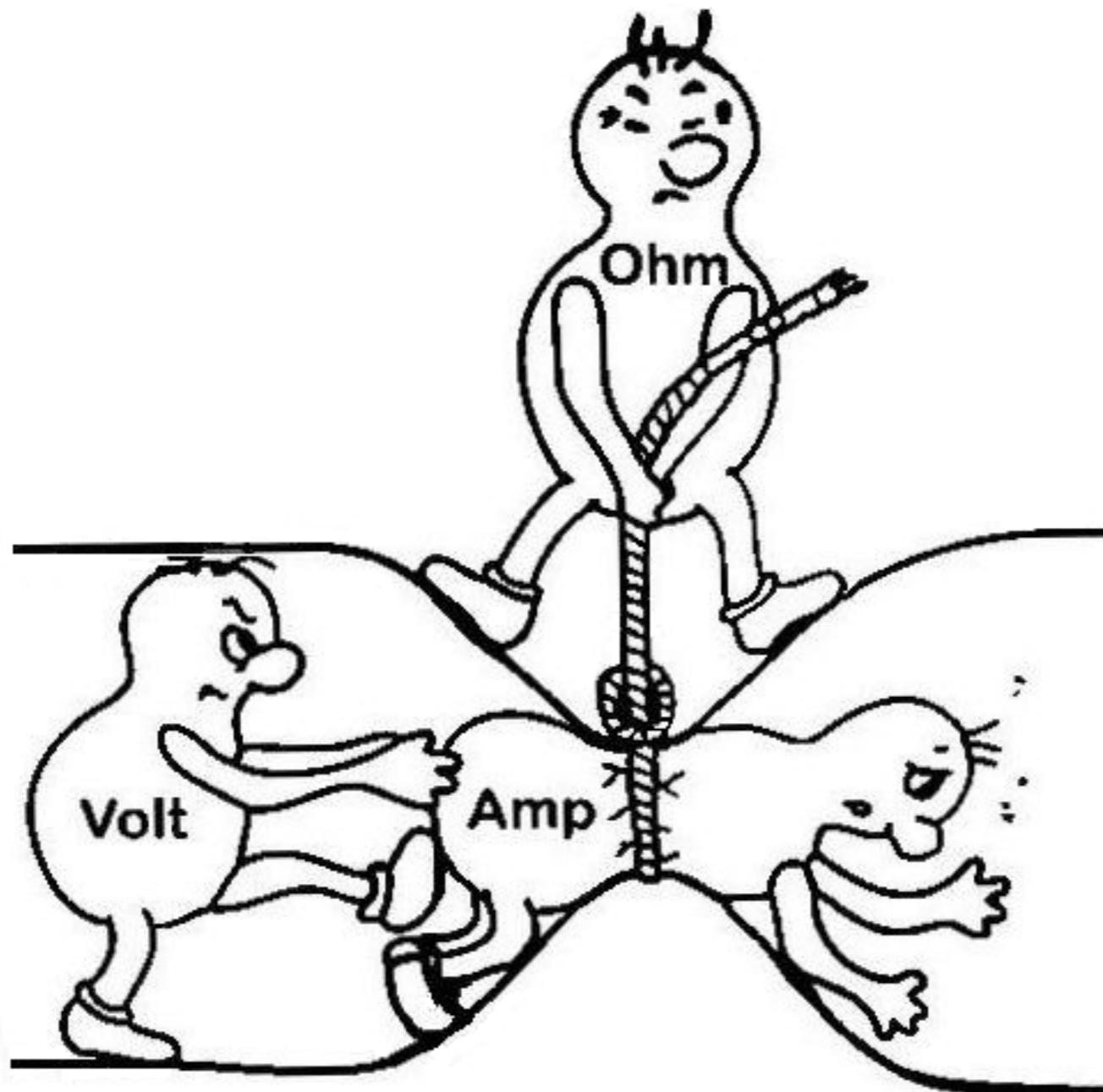


**3600 watt Load = 15amps @  
240v**

**3600 watt Load = 30 amps @  
120v**

## Ohm's Law

**Ohm's law** states that the current (amperage) through a conductor between two points is directly proportional to the potential difference (voltage) across the two points.



## Ohm's Law

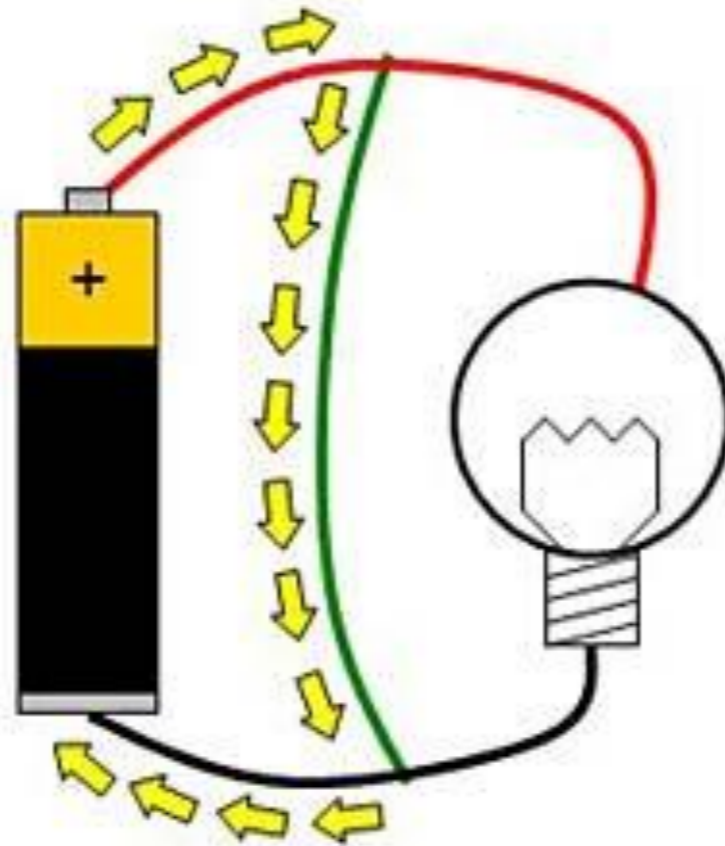
**Ohm's law** states that the current (amperage) through a conductor between two points is directly proportional to the potential difference (voltage) across the two points.

# Fuses & Circuit Breakers



Safety and Control of Electrical Power

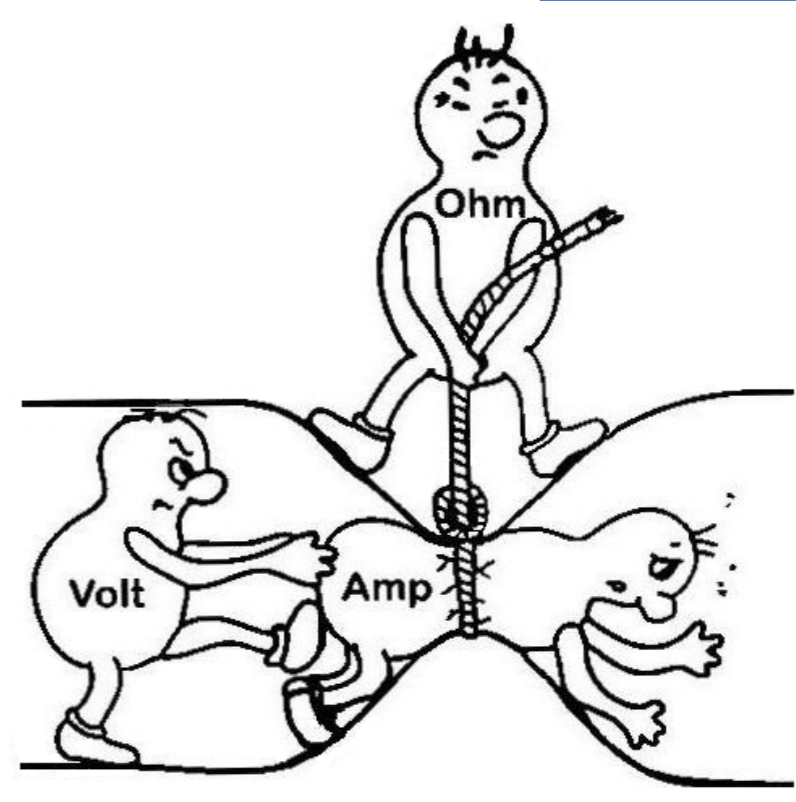
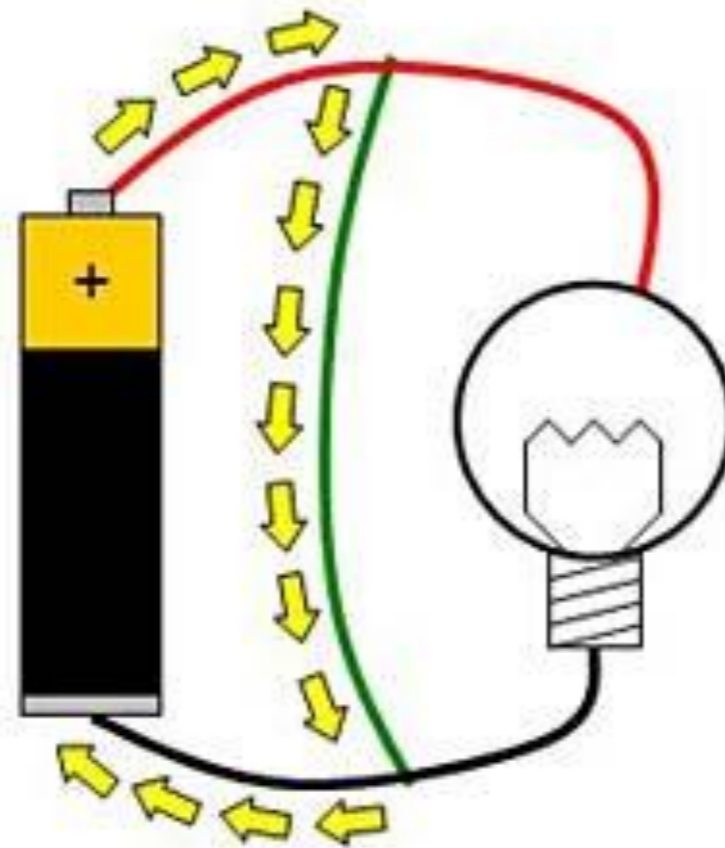
## Short circuit



## Short Circuit

An electrical circuit that allows a current to travel along an unintended path, often where essentially no (or a very low) electrical impedance (resistance) is encountered.

# Short circuit



## Short Circuit

An electrical circuit that allows a current to travel along an unintended path, often where essentially no (or a very low) electrical impedance (resistance) is encountered.



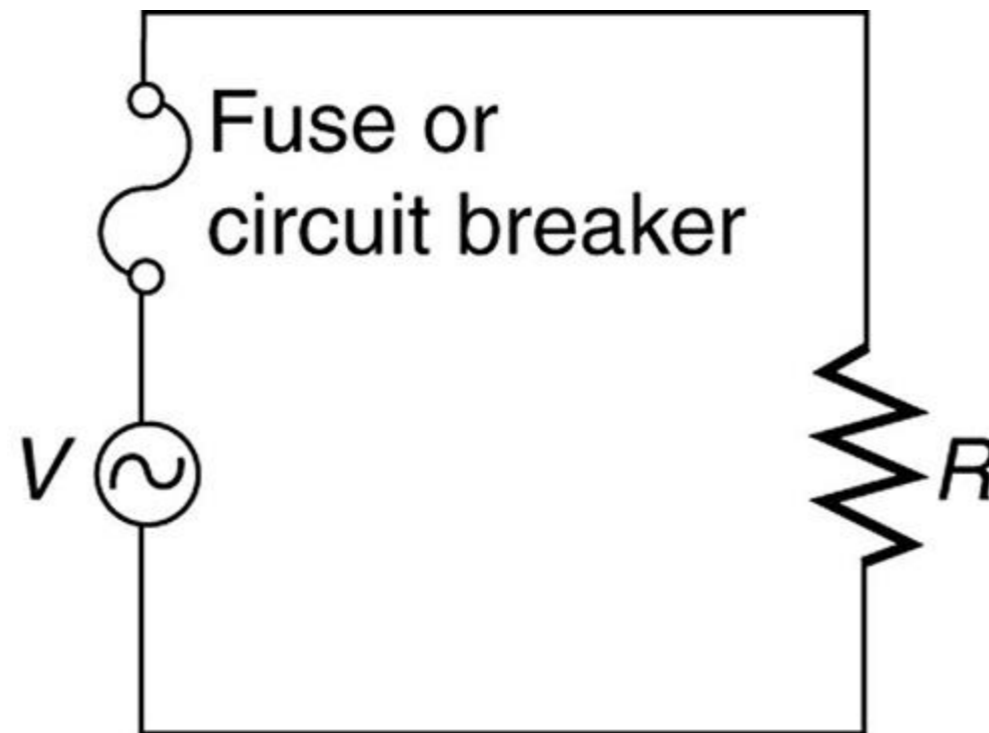
Resistance creates heat. Heat creates resistance.  
Resistance creates heat. Heat creates resistance.  
And so on...

## Short Circuit

An electrical circuit that allows a current to travel along an unintended path, often where essentially no (or a very low) electrical impedance (resistance) is encountered.

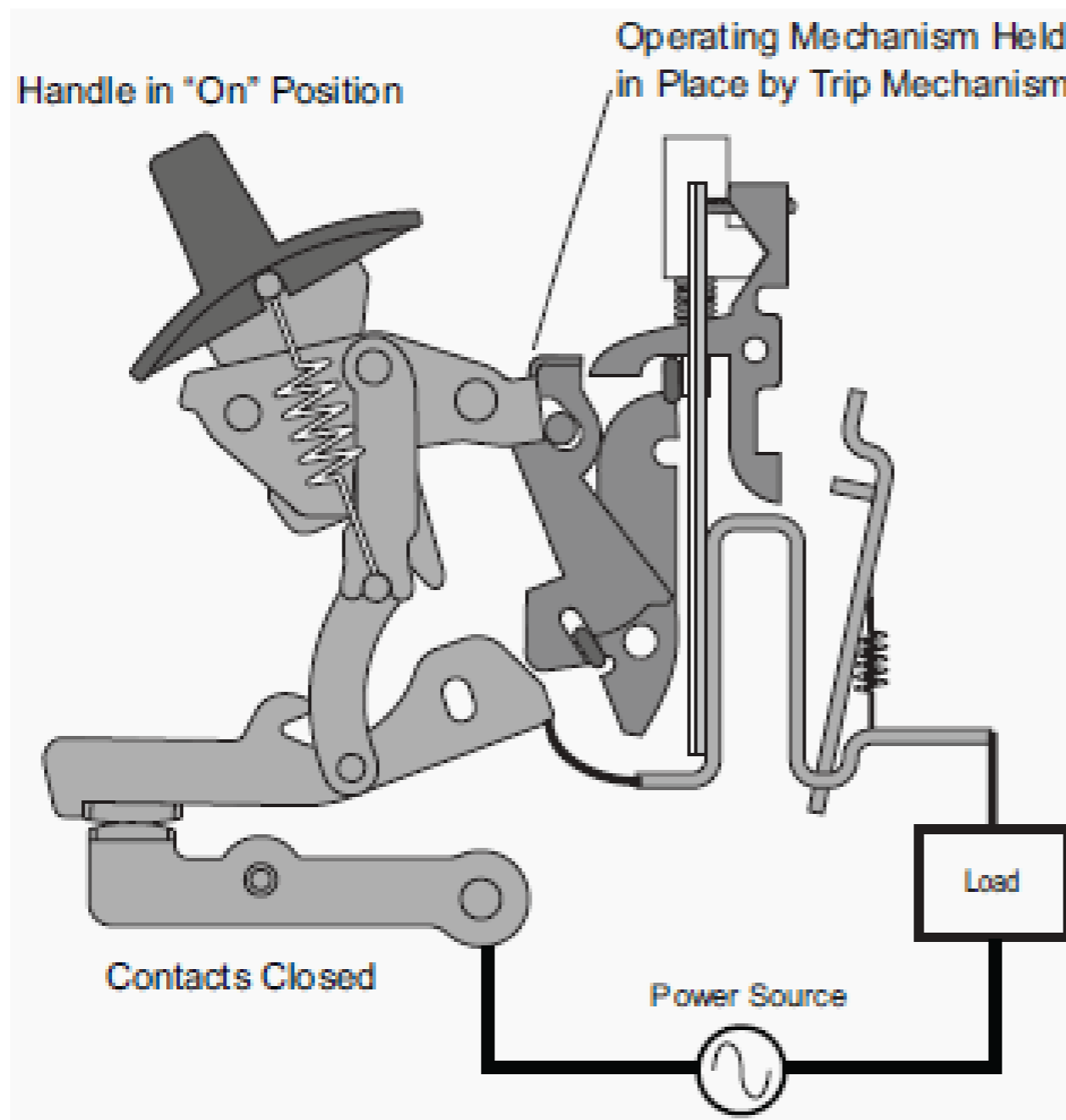


A Fuse is a type of low resistance resistor that acts as a sacrificial device to provide overcurrent protection to the load, power source, and conductors.



## Fuse Protection

A Fuse will limit the potential harmful excessive current. Fuses are usually non-resettable.



## Circuit Breaker Protection

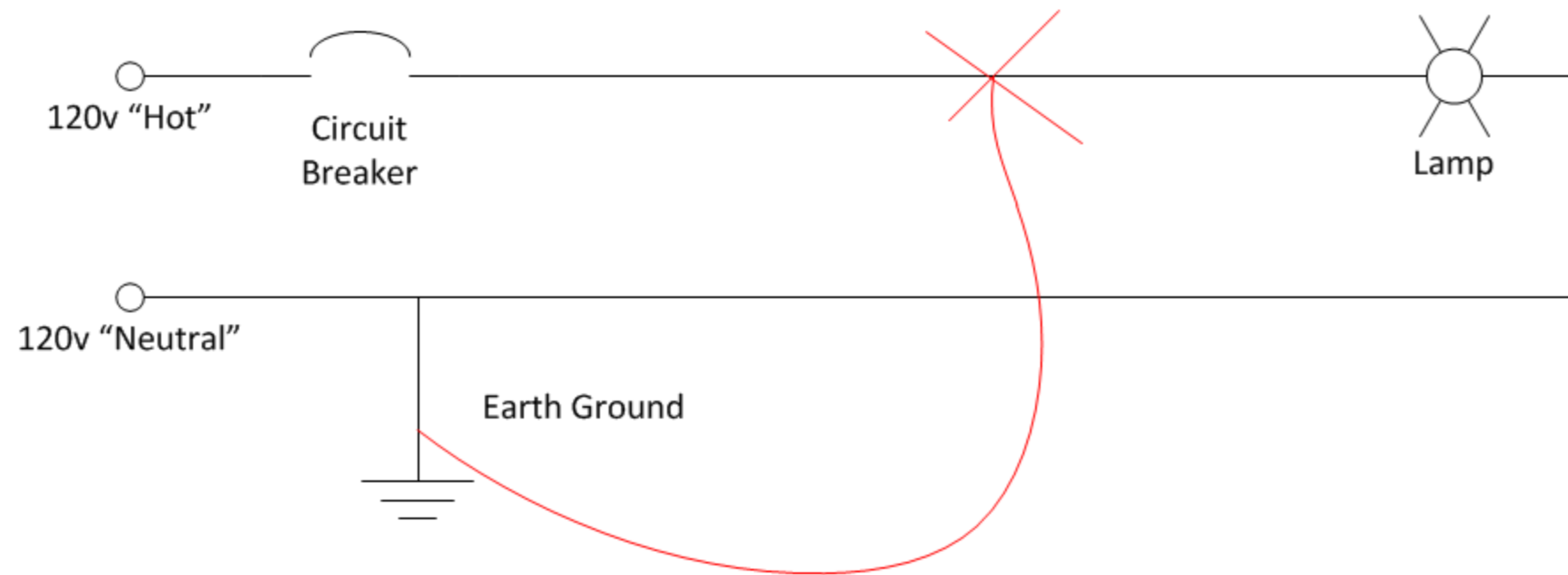
A circuit breaker will open in a fault or over current condition. Circuit breakers can be reset after tripping.



## Neutral – Grounded Conductor

In the US, the Neutral conductor is *grounded* to provide the path back to trip the breaker. Always remember – the Neutral potentially carries the same amount of current as the “hot” conductor.

## Ground Short Circuit



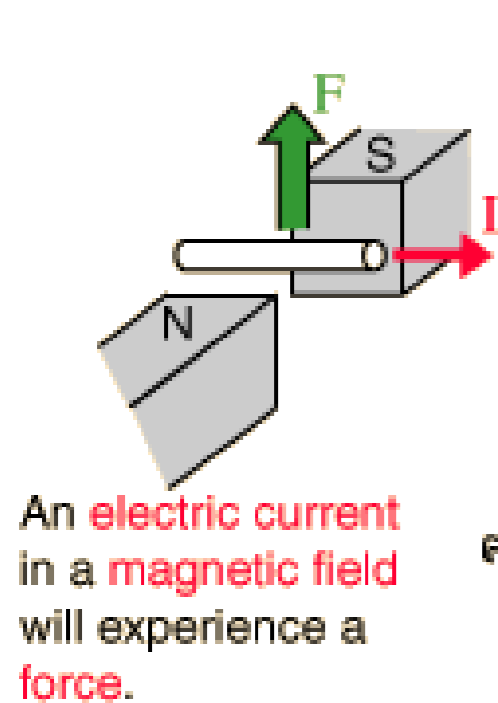
## Neutral – Grounded Conductor

In the US, the Neutral conductor is ***grounded*** to provide the path back to trip the breaker. Always remember – the Neutral potentially carries the same amount of current as the “hot” conductor.

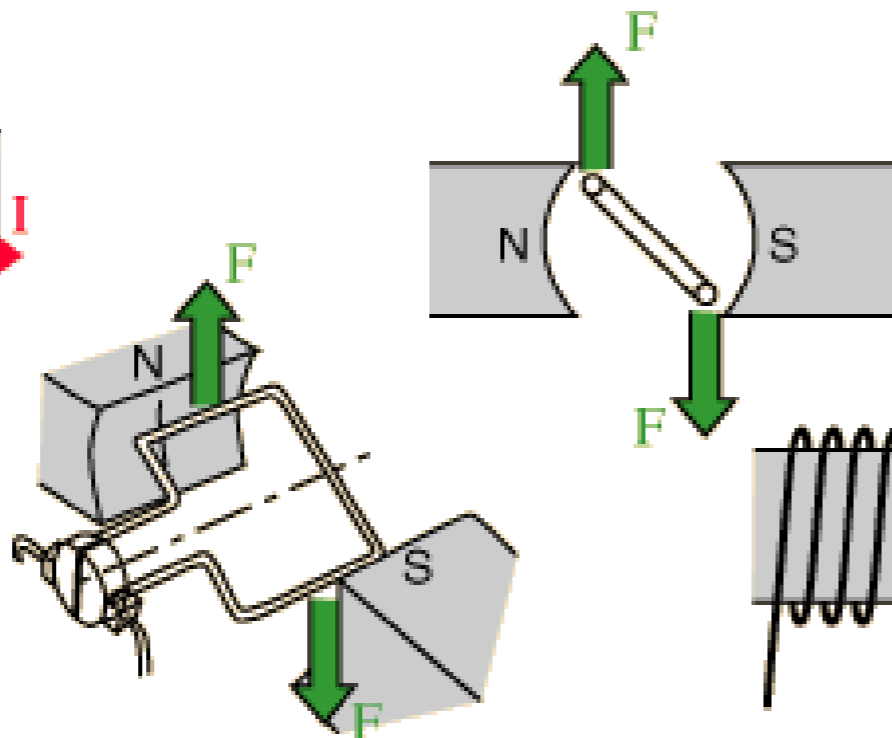
# Motors

Converts electrical energy into mechanical energy.

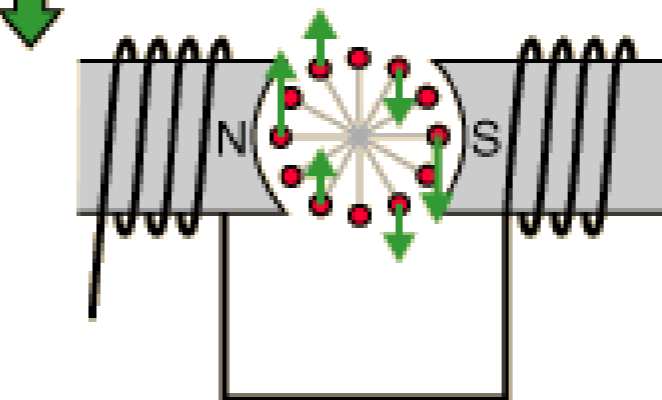




If the current-carrying wire is bent into a loop, then the two sides of the loop which are at right angles to the magnetic field will experience forces in opposite directions.

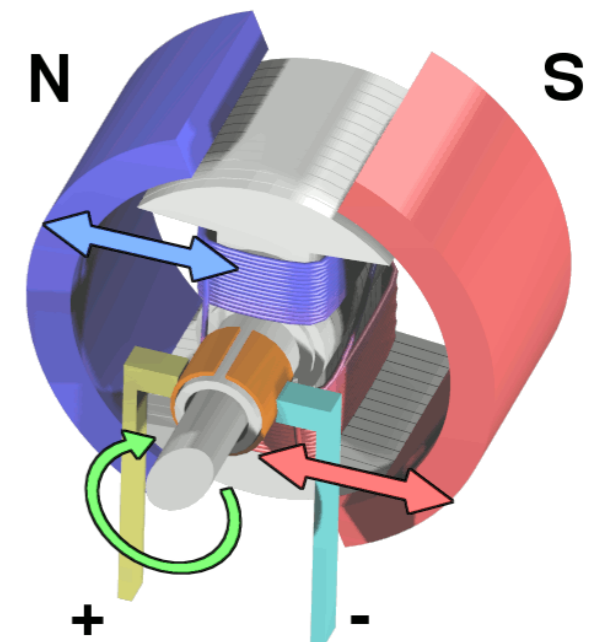


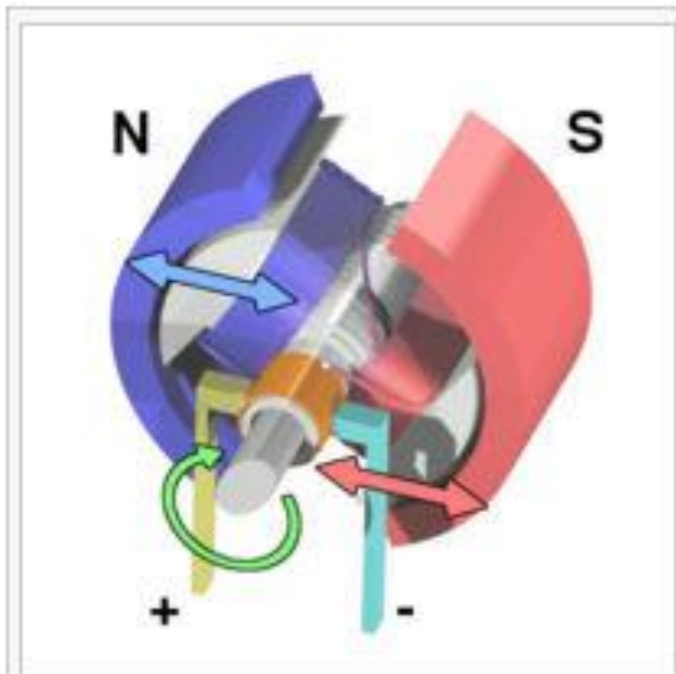
The pair of forces creates a turning influence or **torque** to rotate the coil.



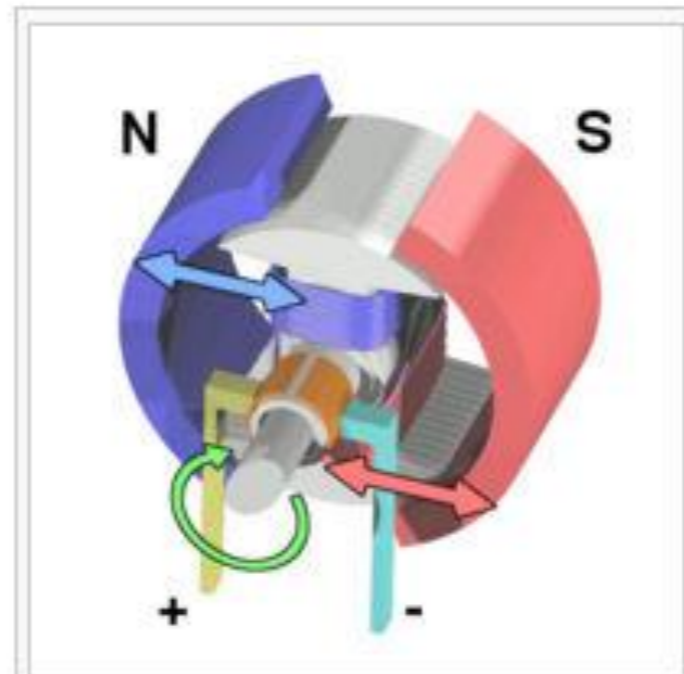
Practical motors have several loops on an **armature** to provide a more uniform torque and the magnetic field is produced by an **electromagnet** arrangement called the field coils.

# Simple DC Motor

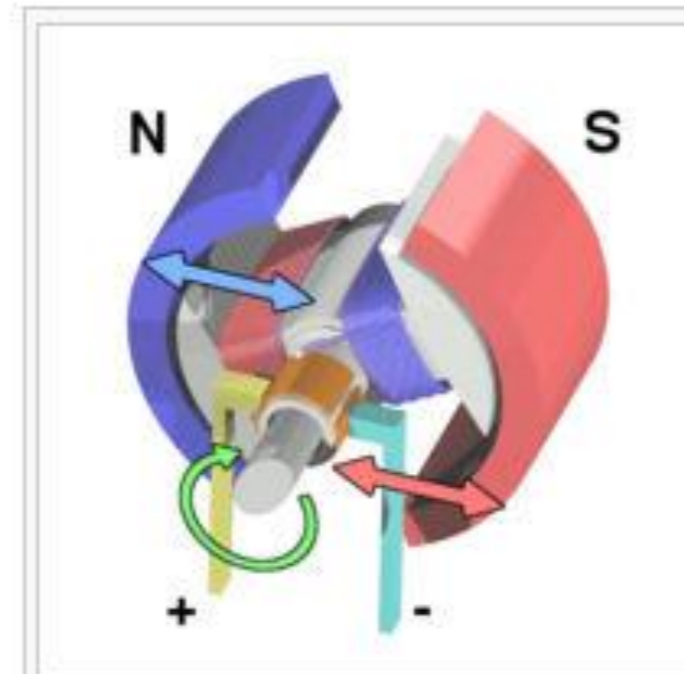




A simple DC electric motor. When the coil is powered, a magnetic field is generated around the armature. The left side of the armature is pushed away from the left magnet and drawn toward the right, causing rotation.

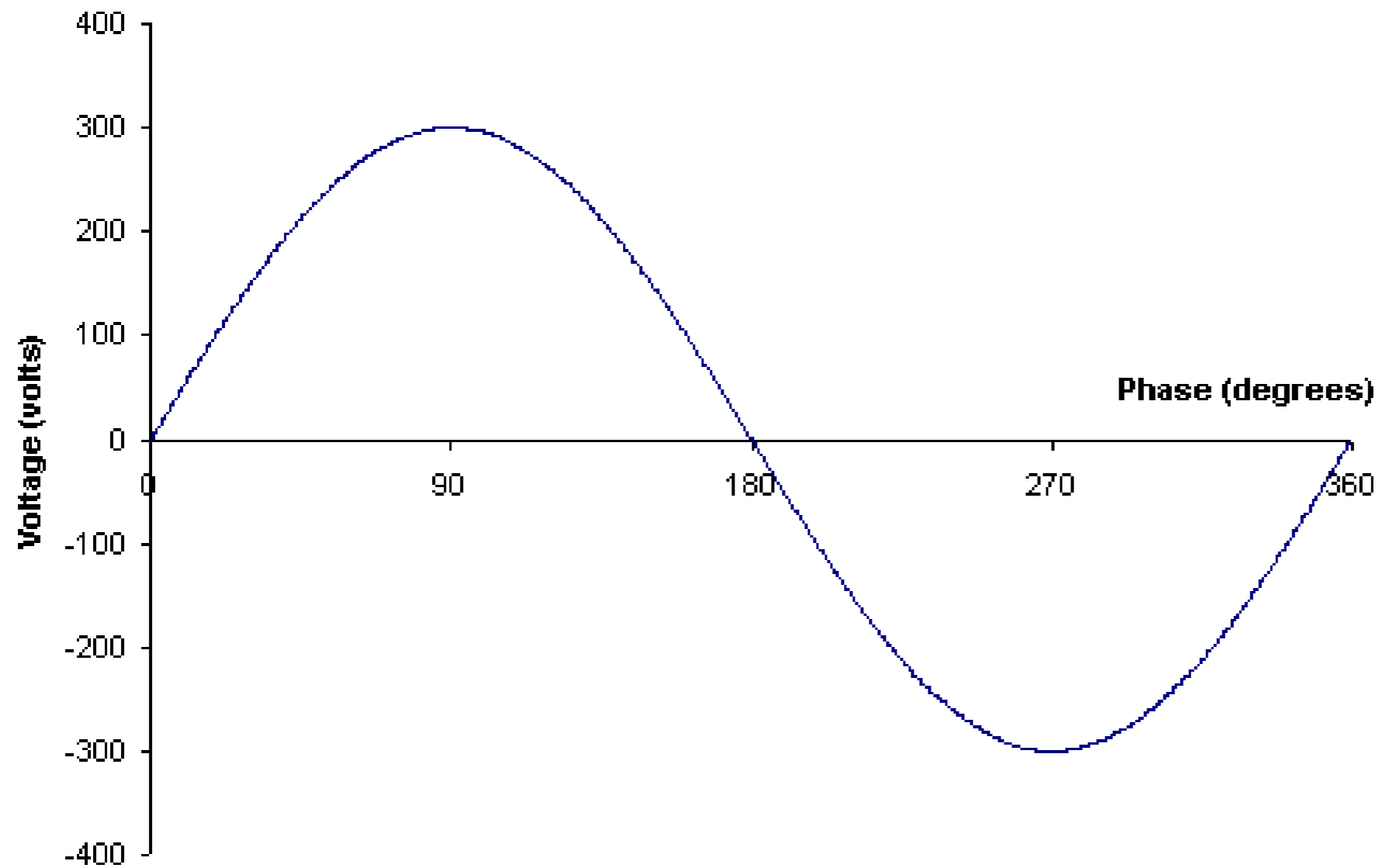


The armature continues to rotate.



When the armature becomes horizontally aligned, the commutator reverses the direction of current through the coil, reversing the magnetic field. The process then repeats.

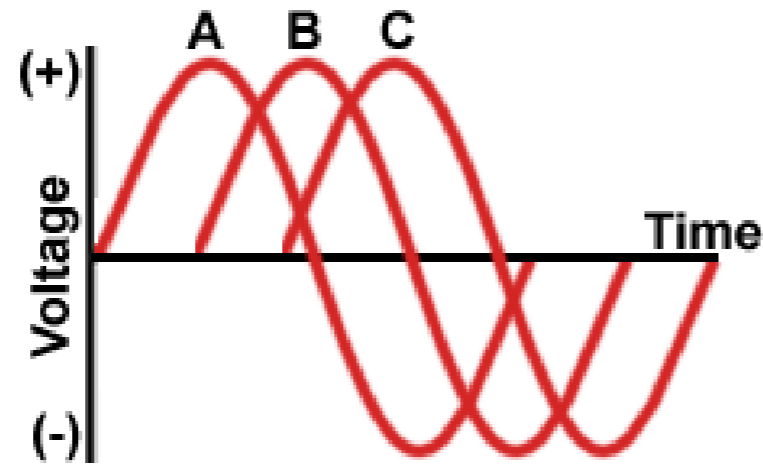
# Simple DC Motor



# Single Phase AC Currents



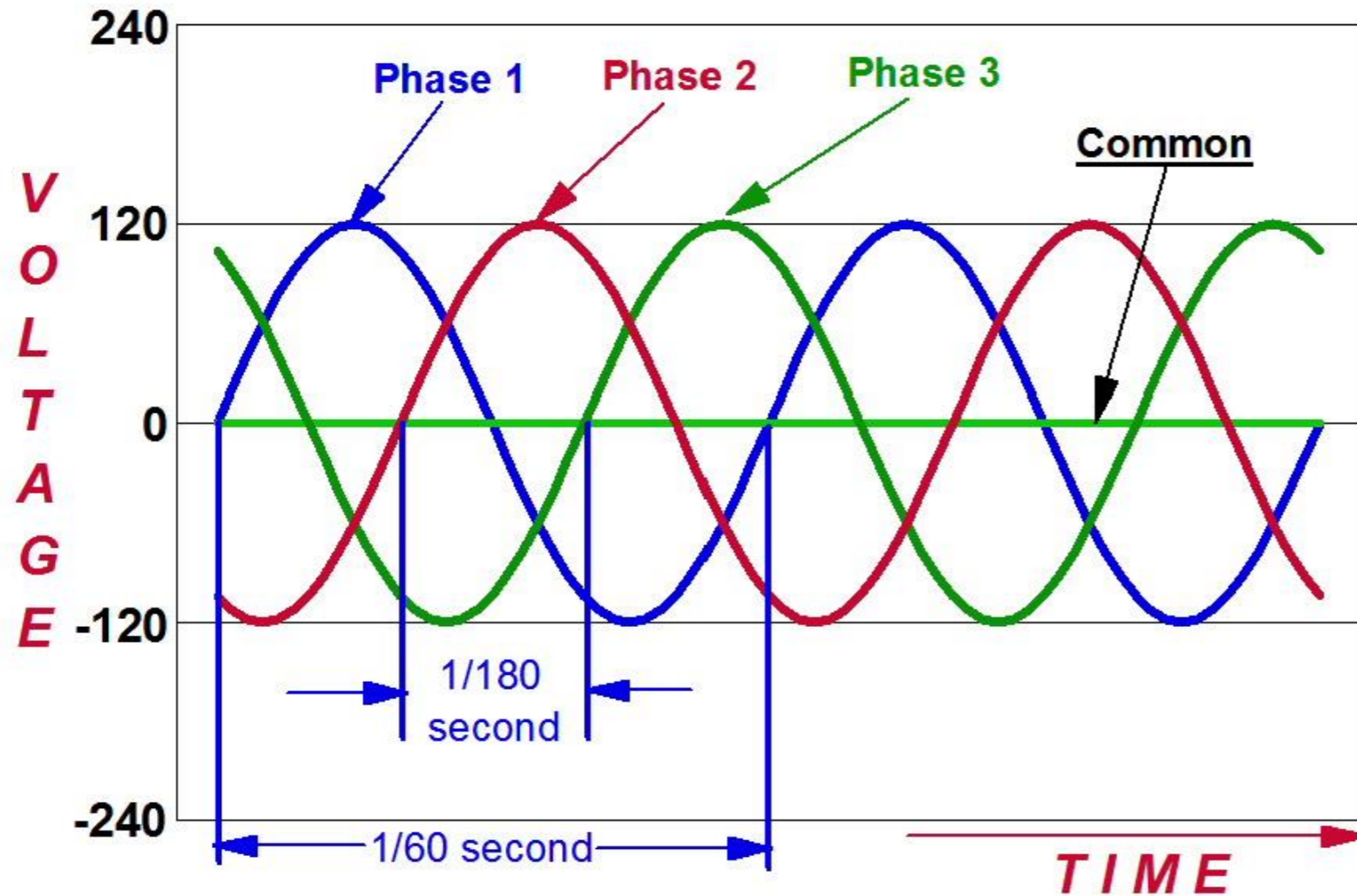
Three-phase power is designed especially for large electrical loads where the total electrical load is divided among the three separate phases. As a result, the wire and transformers will be less expensive than if these large loads were carried on a single-phase system.



Three phase generators usually have three separate windings, each producing its own separate single-phase voltage. Since these windings are staggered around the generator circumference, each of the single-phase voltages is "out of phase" 120 deg with one another. That is, each of the three reaches the maximum and minimum points in the AC cycle at different times.

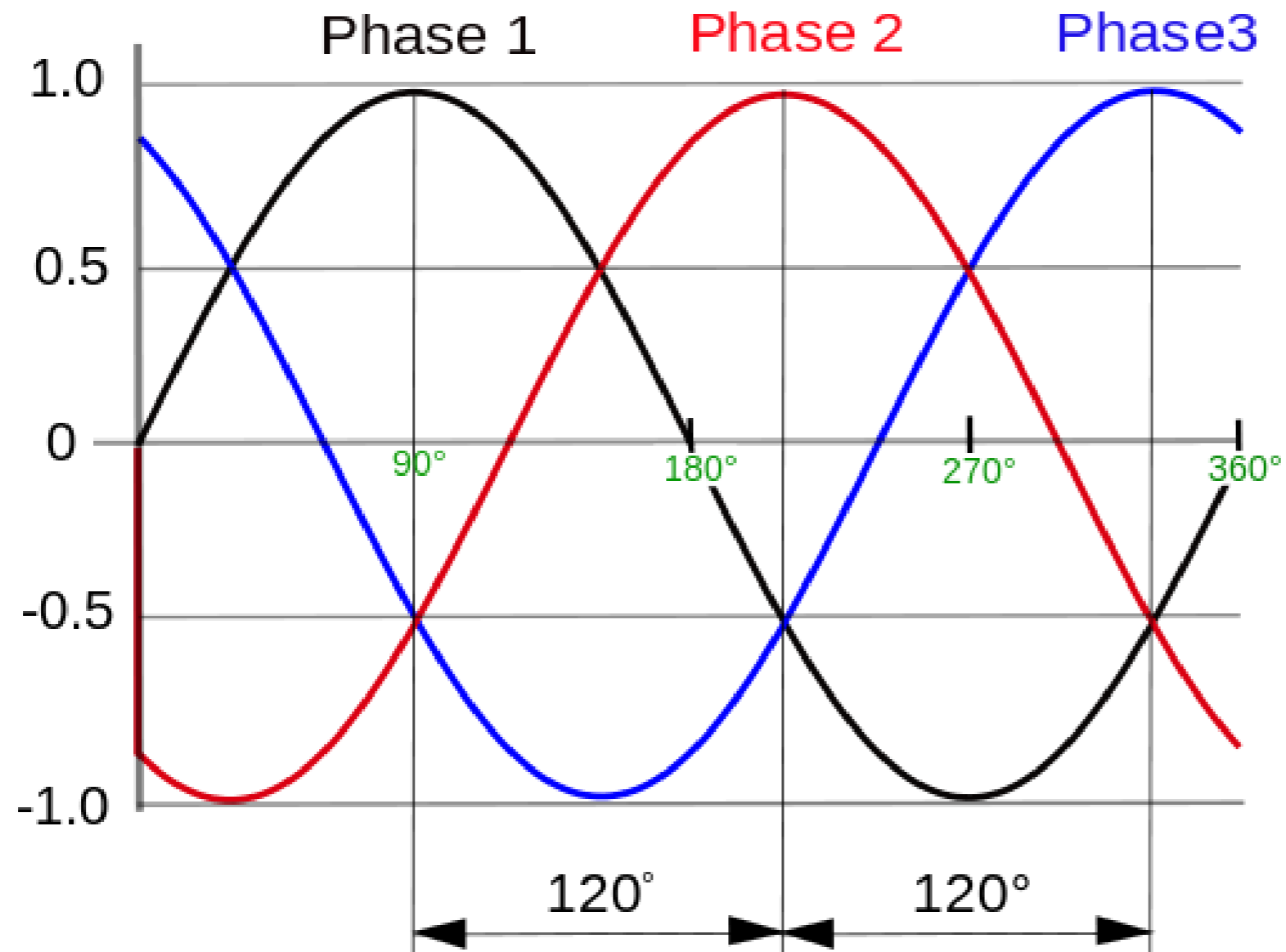
## Three Phase AC Currents

# Three Phase Power



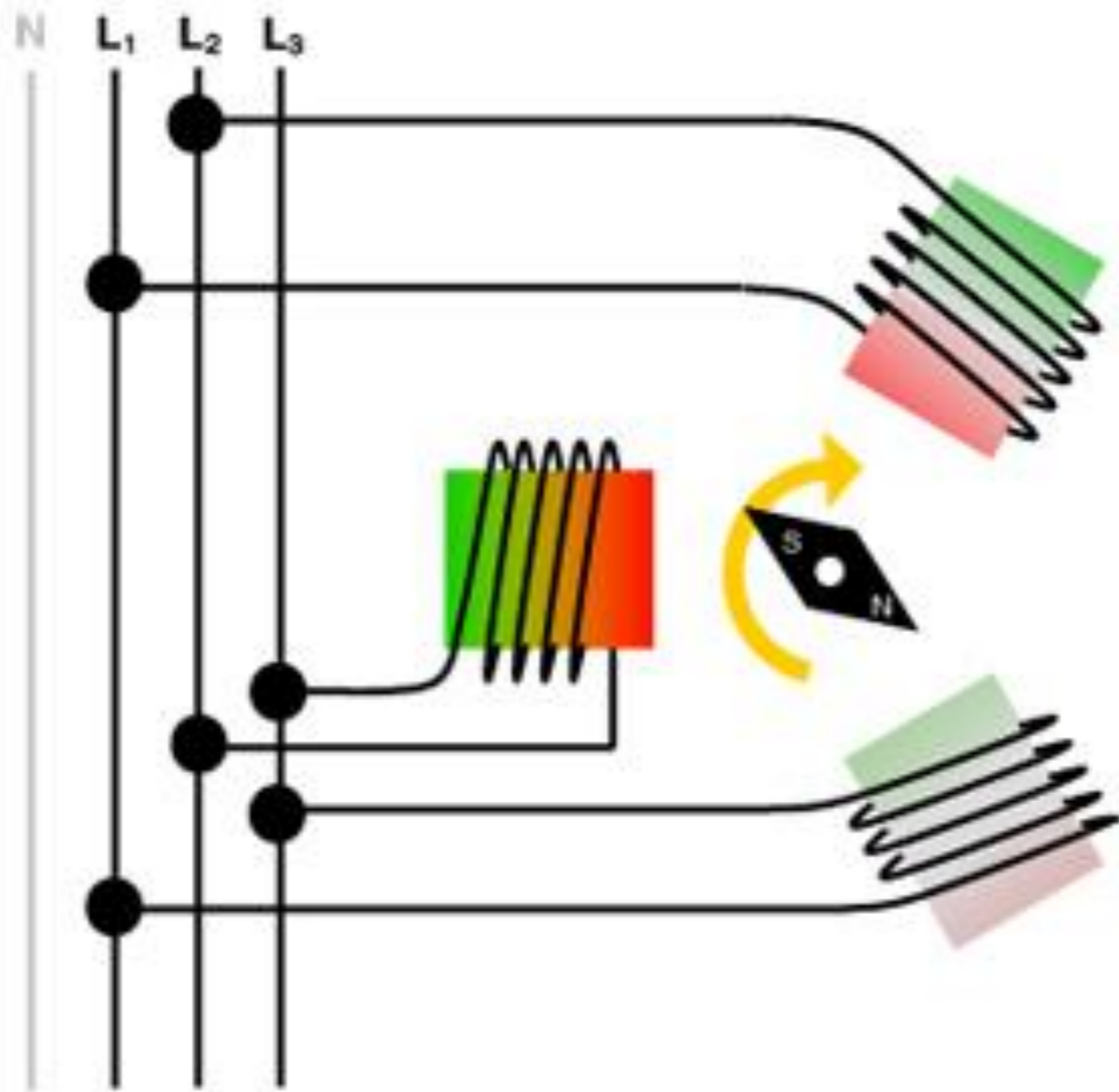
## Three Phase AC Currents

Three-phase power is designed especially for large electrical loads where the total electrical load is divided among the three separate phases. As a result, the wire and transformers will be less expensive than if these large loads were carried on a single-phase system.



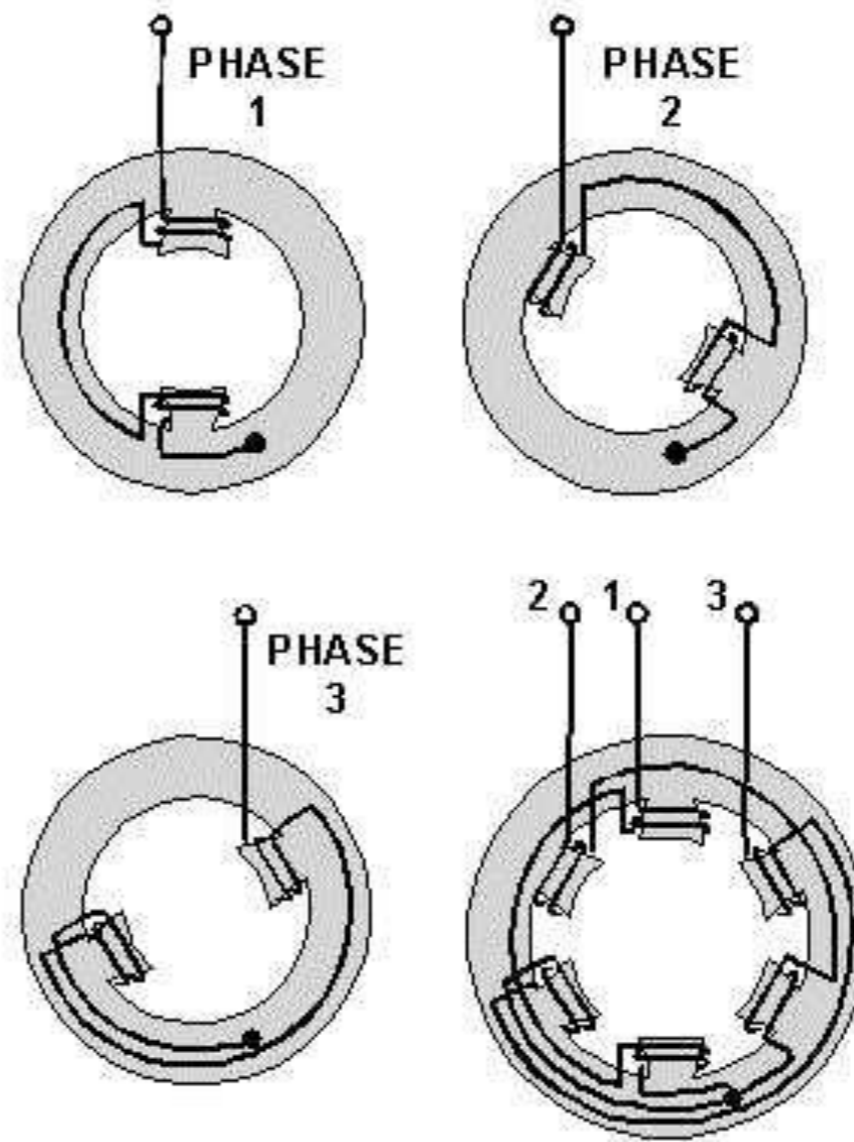
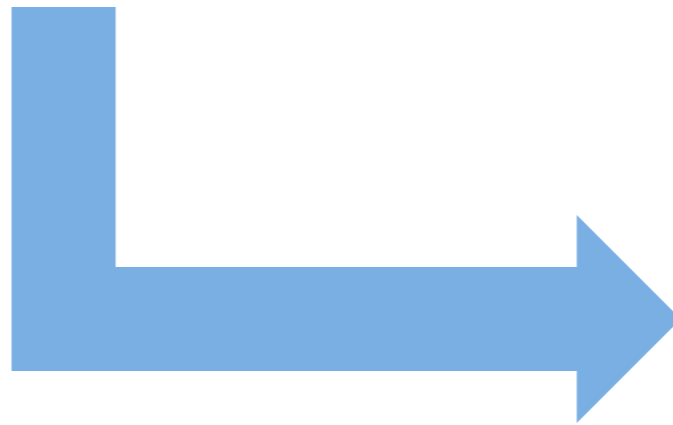
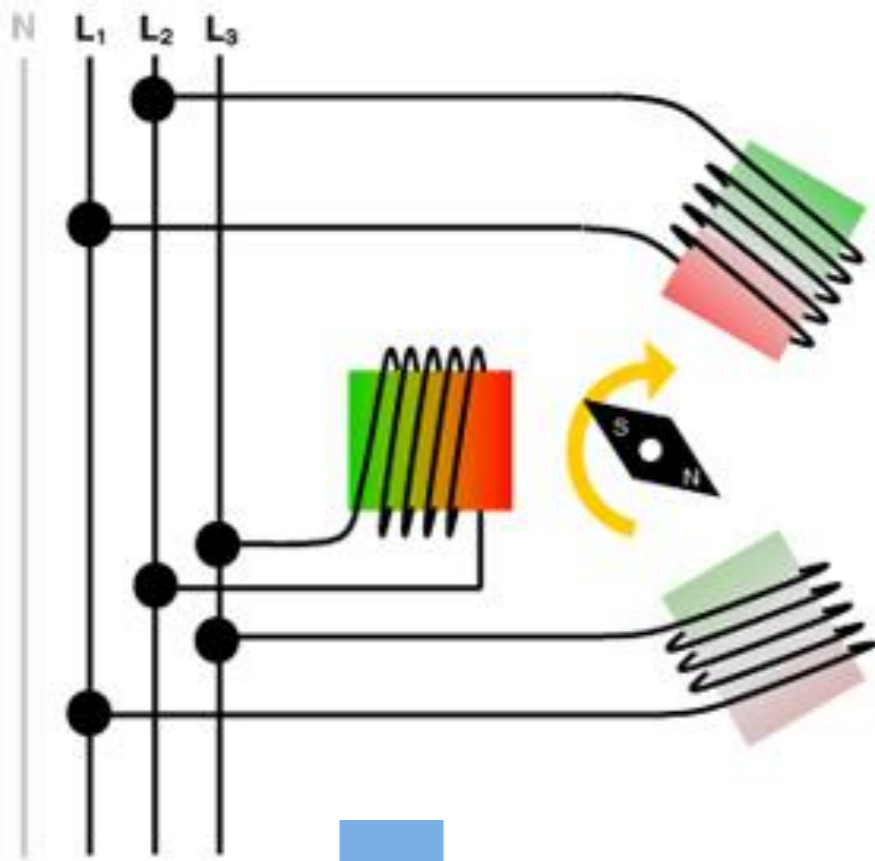
## Three Phase AC Currents

Three-phase power is designed especially for large electrical loads where the total electrical load is divided among the three separate phases. As a result, the wire and transformers will be less expensive than if these large loads were carried on a single-phase system.



# Three Phase AC Motor Fields

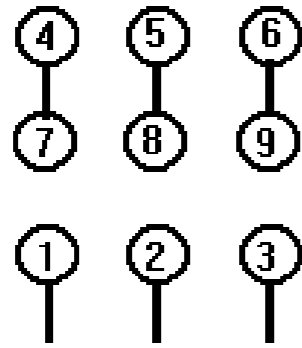
Three-phase power in a motor



# Three Phase AC Motor Fields

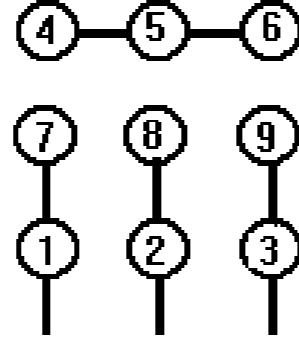
Three-phase power – Field Windings

HIGH VOLTAGE

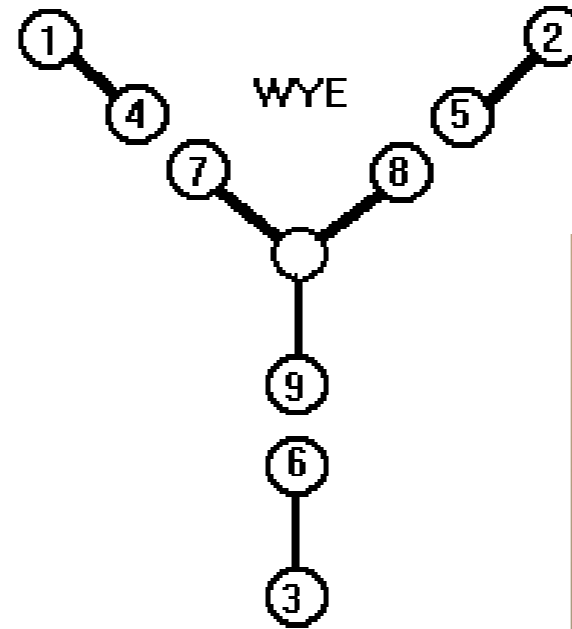


LINE

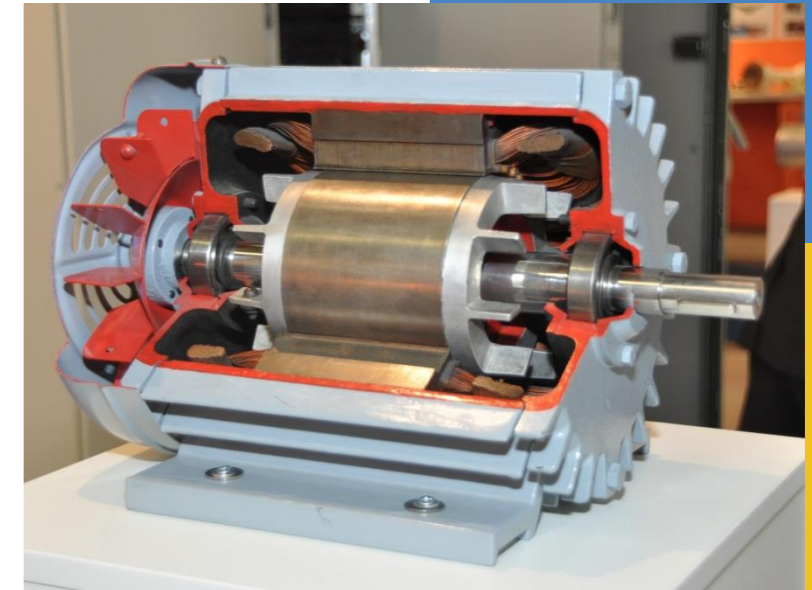
LOW VOLTAGE



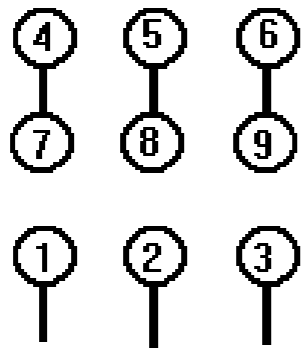
LINE



WYE

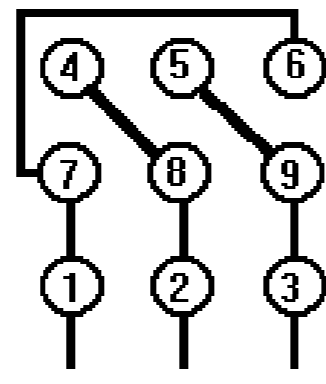


HIGH VOLTAGE

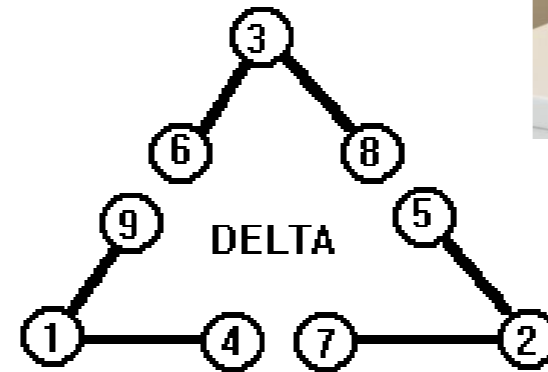


LINE

LOW VOLTAGE



LINE



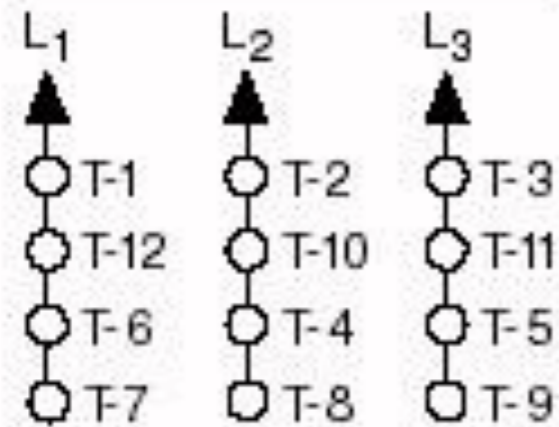
DELTA

# Three Phase AC Motor Fields

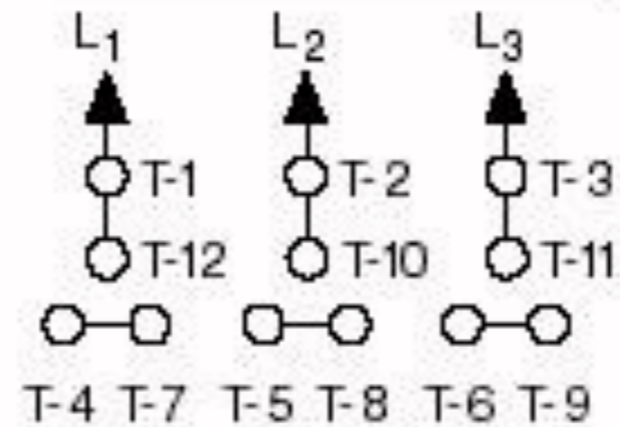
Three-phase power – 9 wire Field Windings

## Dual Voltage, 12 Leads Across The Line Start Connection

### LOW VOLTAGE LINE

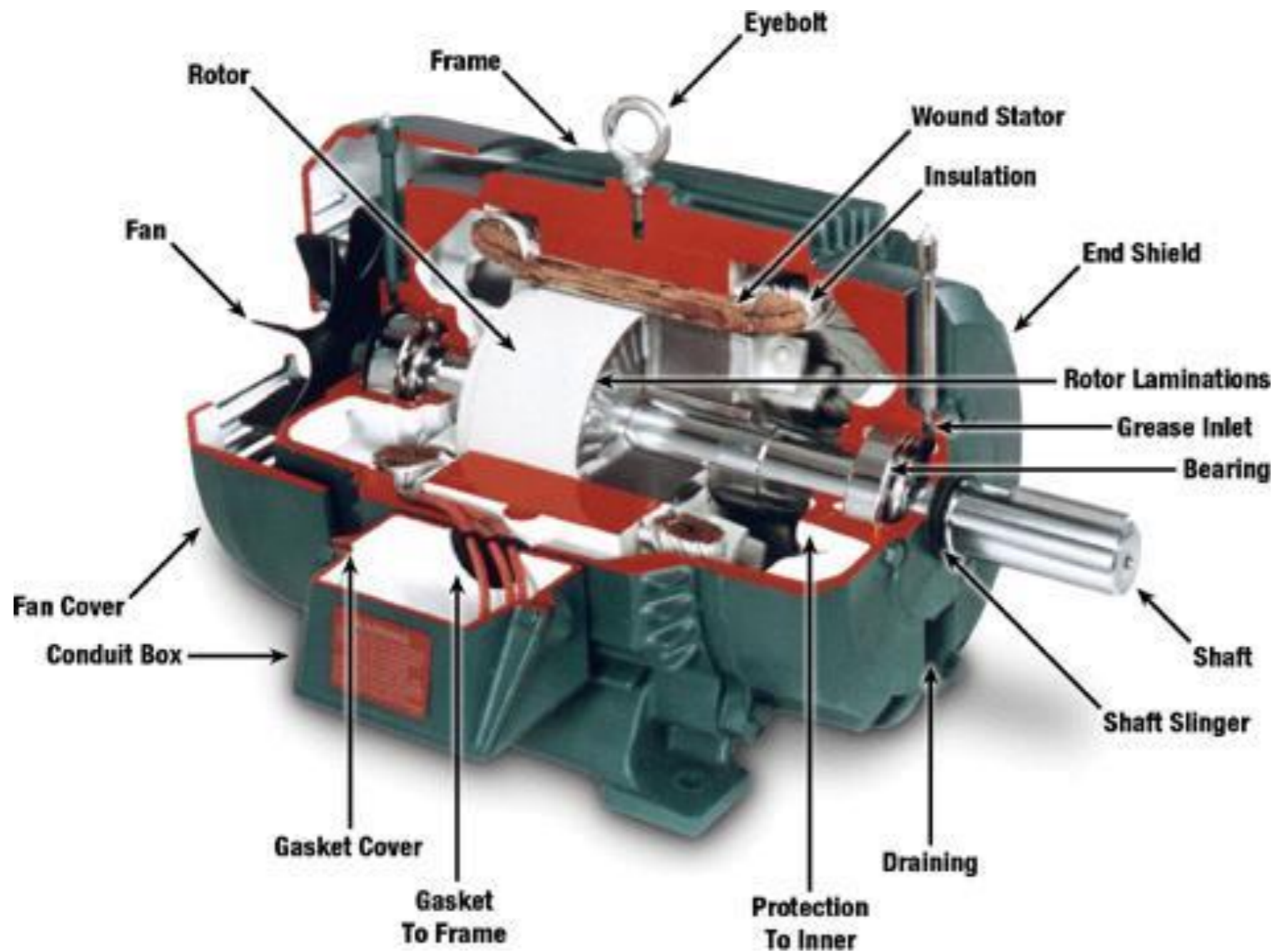


### HIGH VOLTAGE LINE



# Three Phase AC Motor Fields

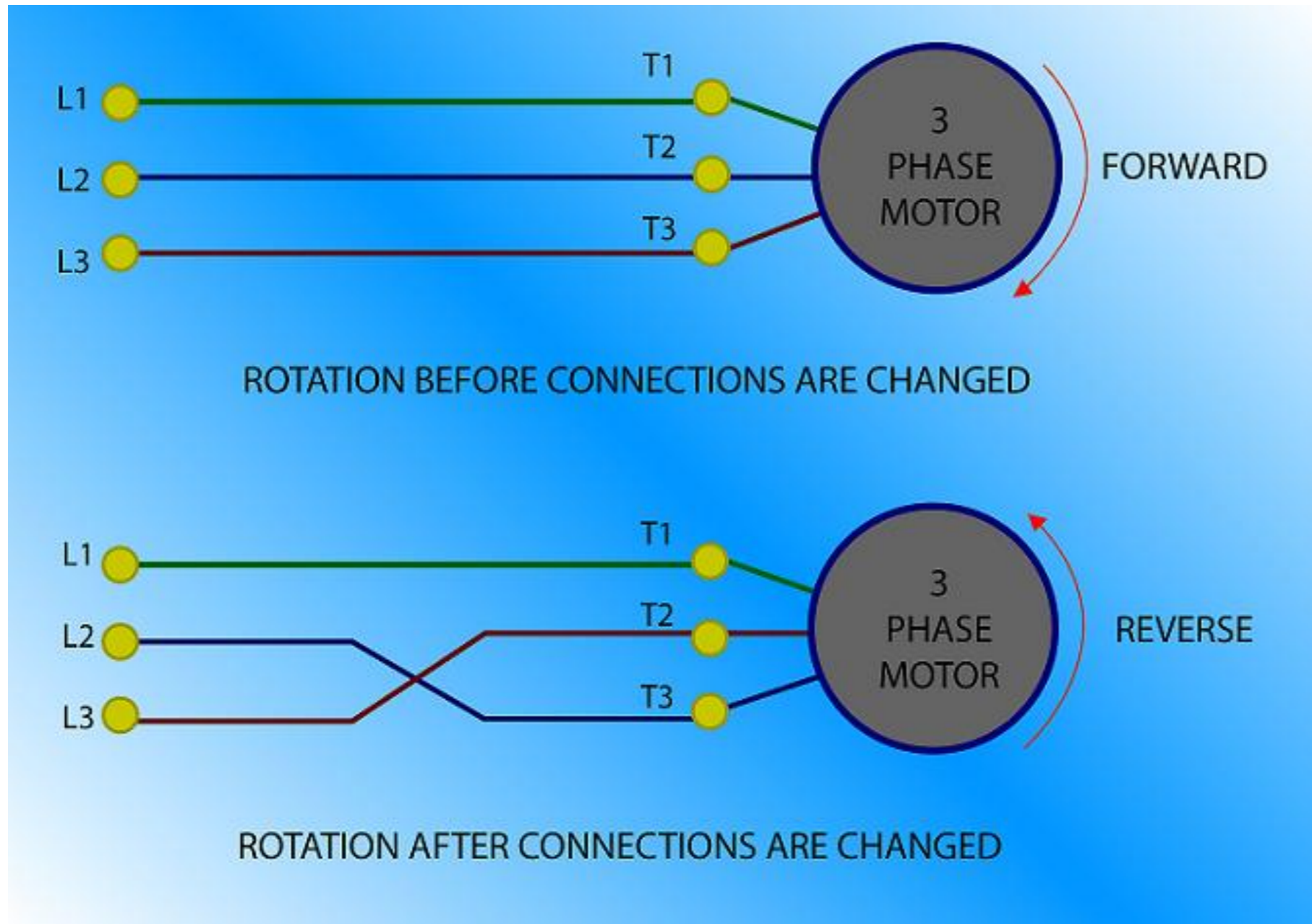
Three-phase power – 12 wire Field Windings



# Three Phase AC Induction Motor

A Motor is a machine that converts electrical energy into Mechanical energy





## Three Phase Induction Motor Rotation

Reversing the Phase Conductors will reverse the motor's direction of travel

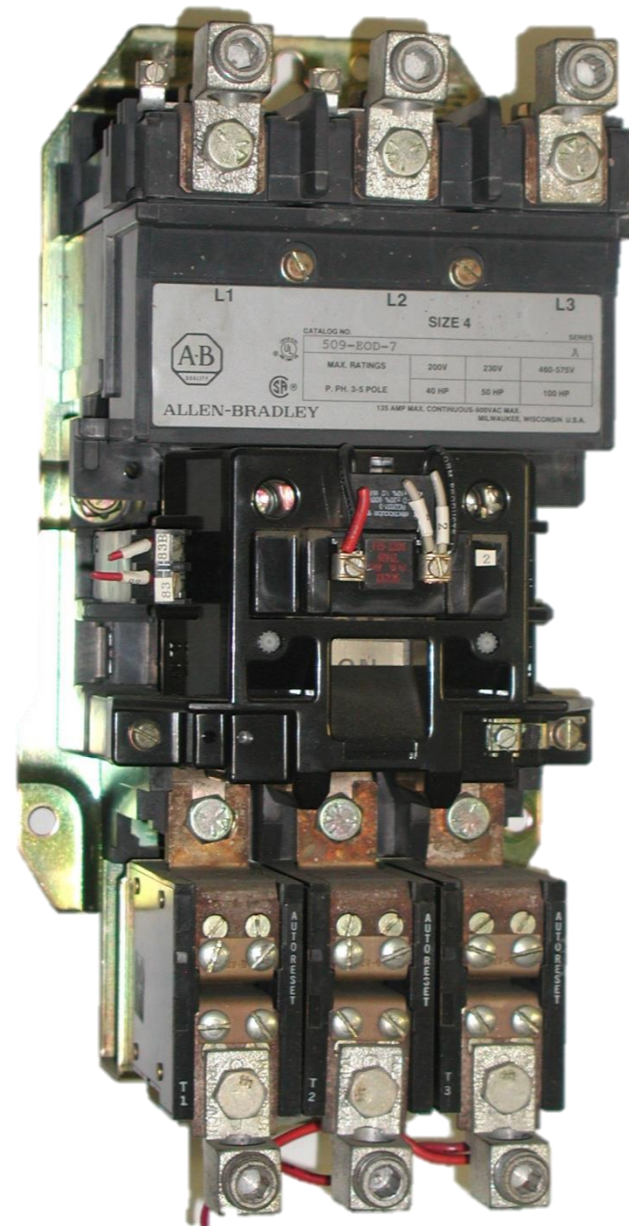
# Motor Controls

Motor Starters

Variable Speed Drives

Soft Starters

# NEMA Type Motor Starter



Coil

Contactor

Auxiliary  
Contacts

Overload Relay

Heaters

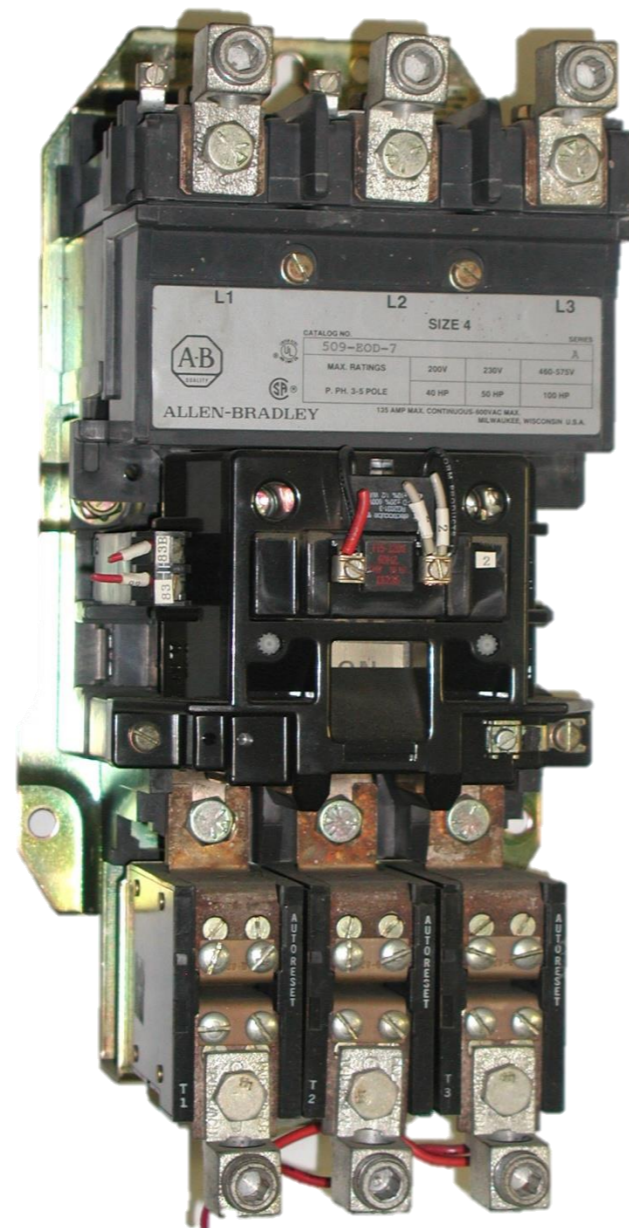
## Across The Line Motor Starters

A motor starter consists of a Contactor and an Overload Protection Device.



Coil

Overload Relay



NEMA Type  
Motor Starter

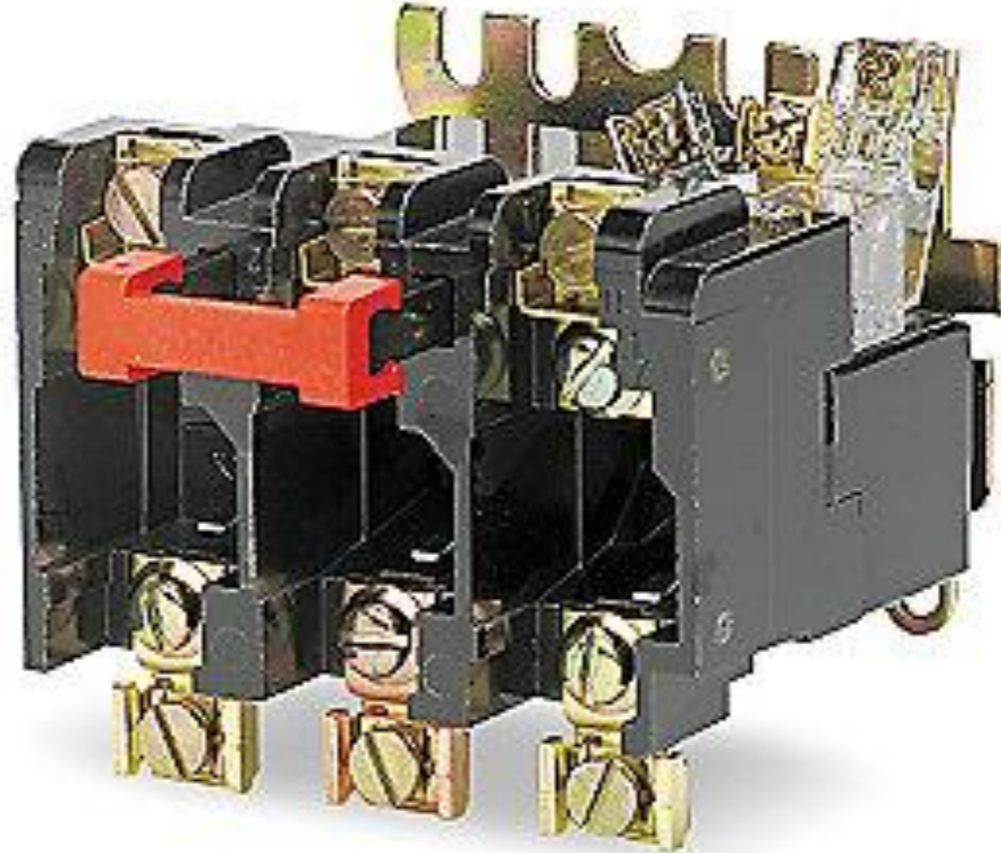
Contactor

Auxiliary  
Contacts

Heaters

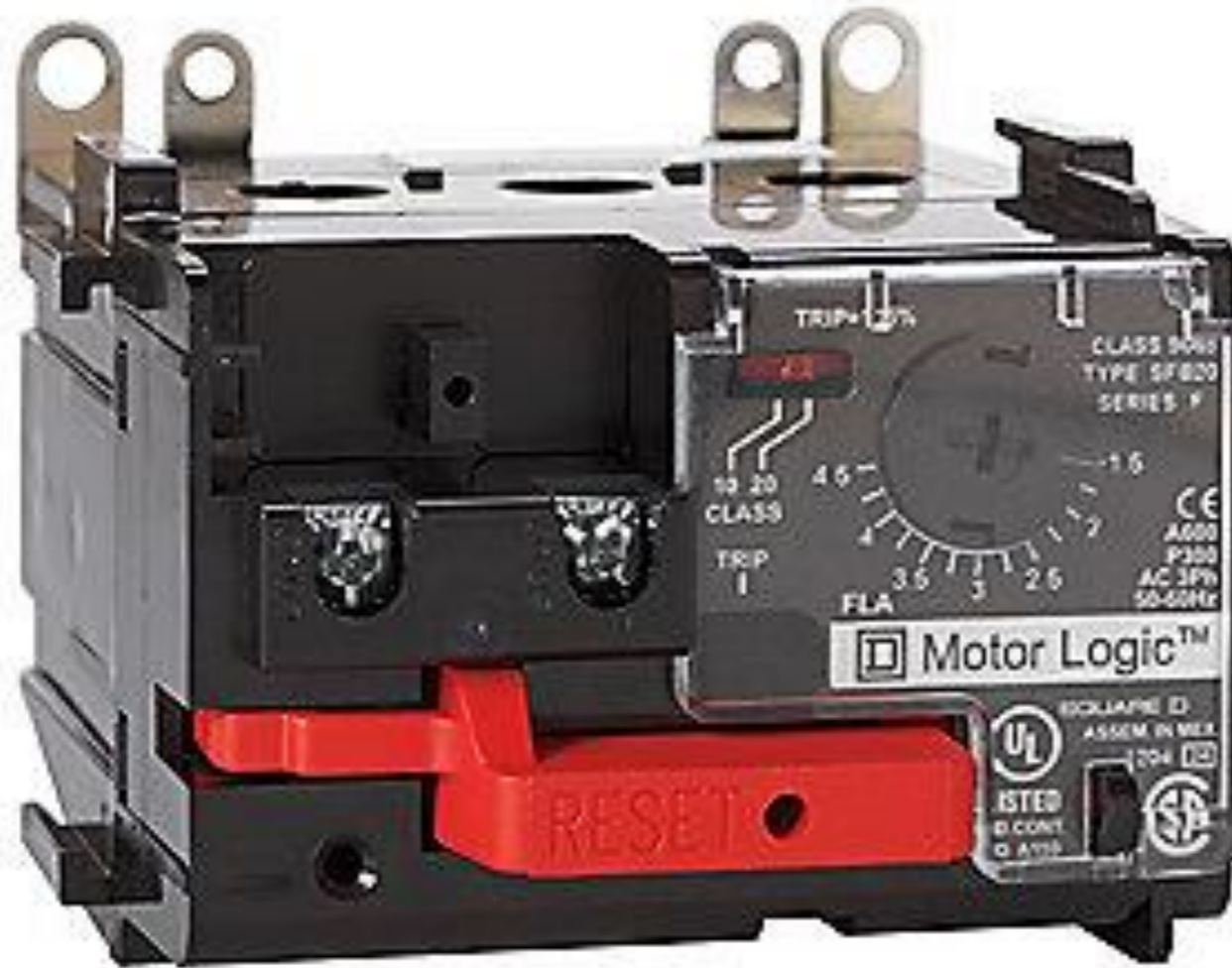
# Across The Line Motor Starters

The Contactor's purpose is to apply power to the load, and open as required, safely extinguishing any arc produced. The contactor coil uses an auxiliary control circuit to close and open the contactor.



## Overload Relay – Heater Type

The Overload Relay is designed to protect the motor from loads in excess of its design. Often a Thermal Heater is used to provide that protection.



## Overload Relay – Thermal Type

The Overload Relay is designed to protect the motor from loads in excess of it's design.



**IEC Type  
Motor Starter**

# Across The Line Motor Starters

“International Electrotechnical Commission”

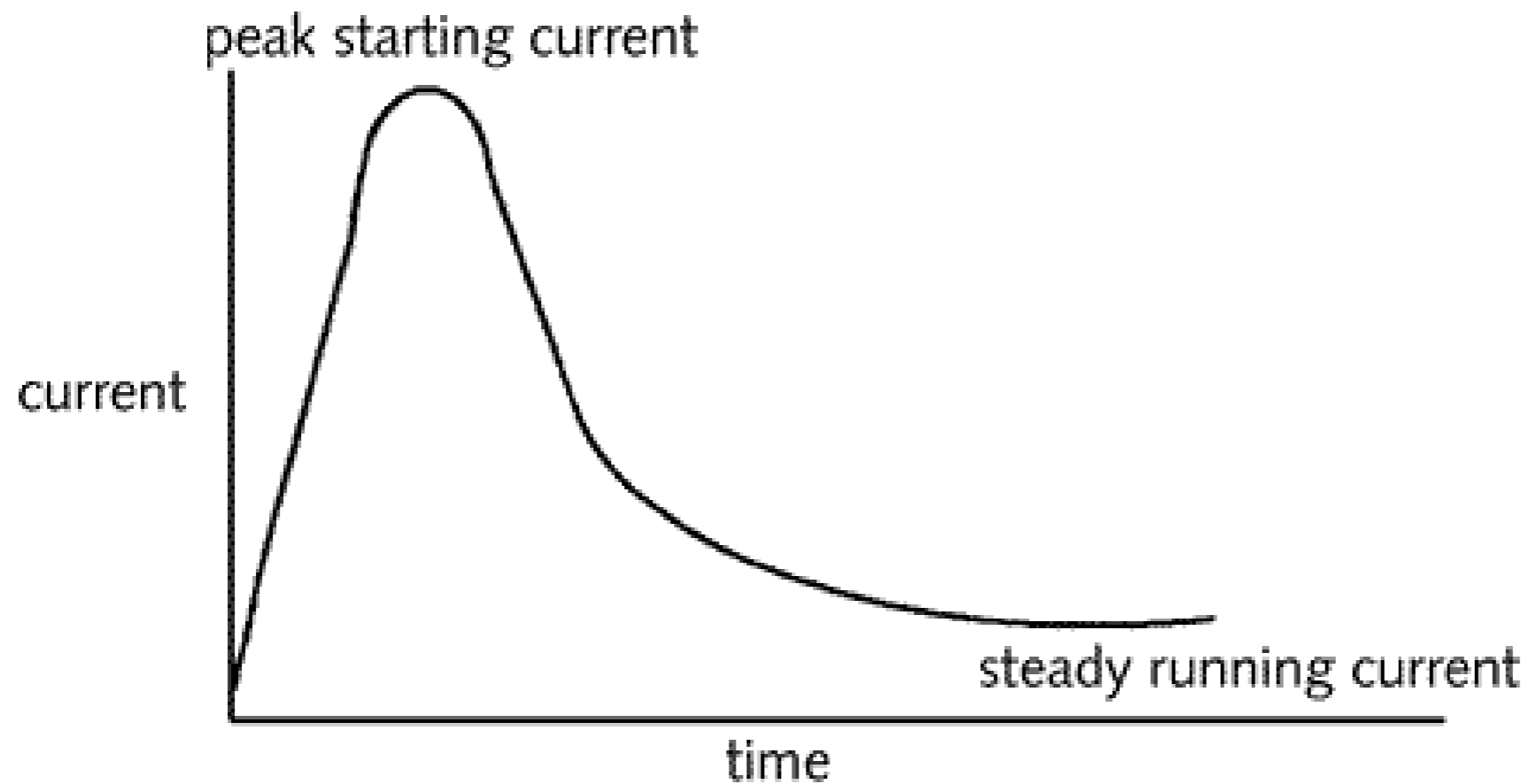


IEC Type  
Combination  
Motor Starter

## Across The Line Motor Starters

This combination starter provides a disconnect, short circuit (fault) protection, and thermal overload protection.





## In-rush Start up Current

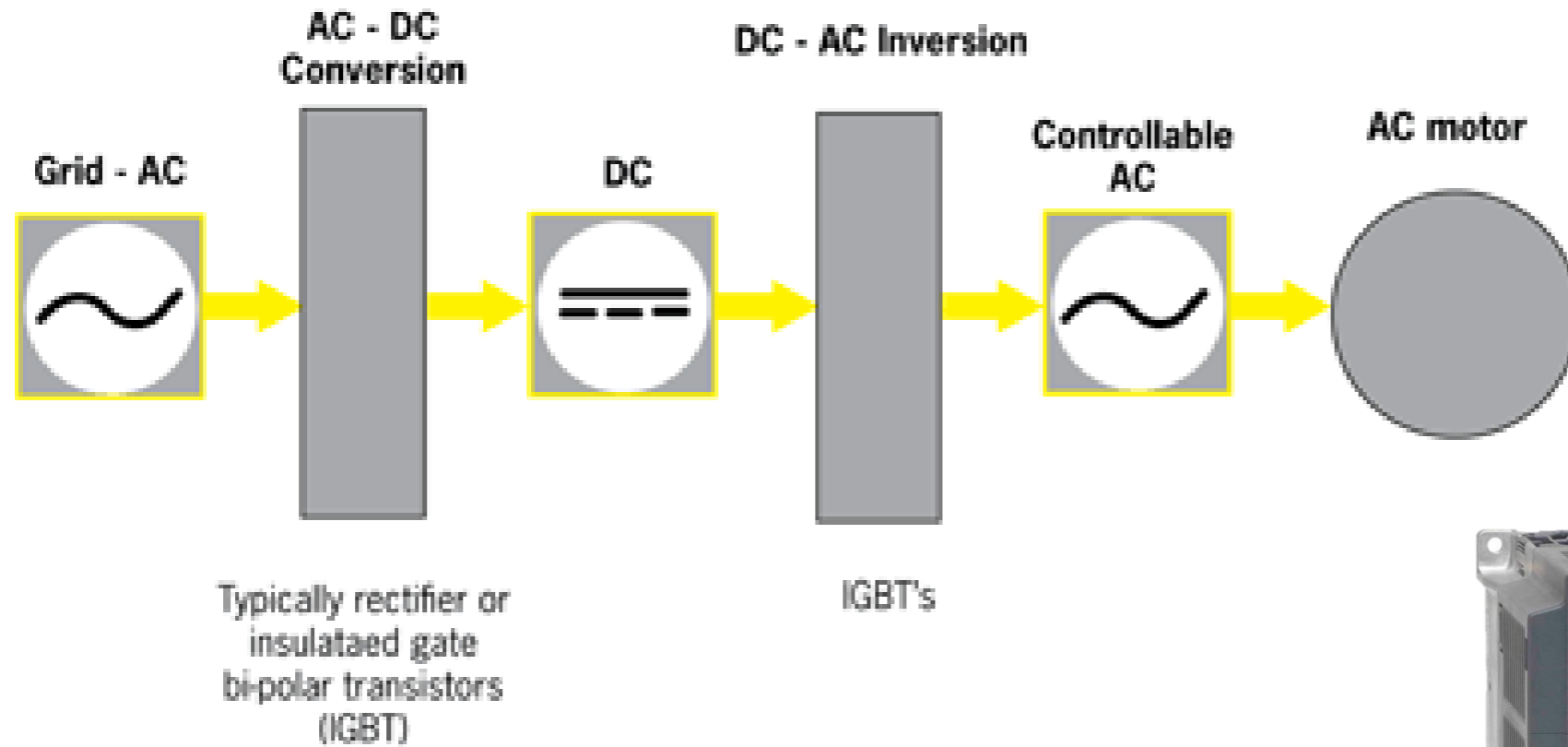
When an AC motor is energized, a high inrush current occurs. After the first half-cycle the motor begins to rotate and the starting current subsides to 4 to 8 times the normal current for several seconds.



# Variable Frequency Drives

A Solid State Motor Control Device that can vary the speed and torque of an AC motor.

## VFD basics



Insulated Gate Bipolar Transistors



# Variable Frequency Drives

A Solid State Motor Control Device that can vary the speed and torque of an AC motor.



*Also Provides:*

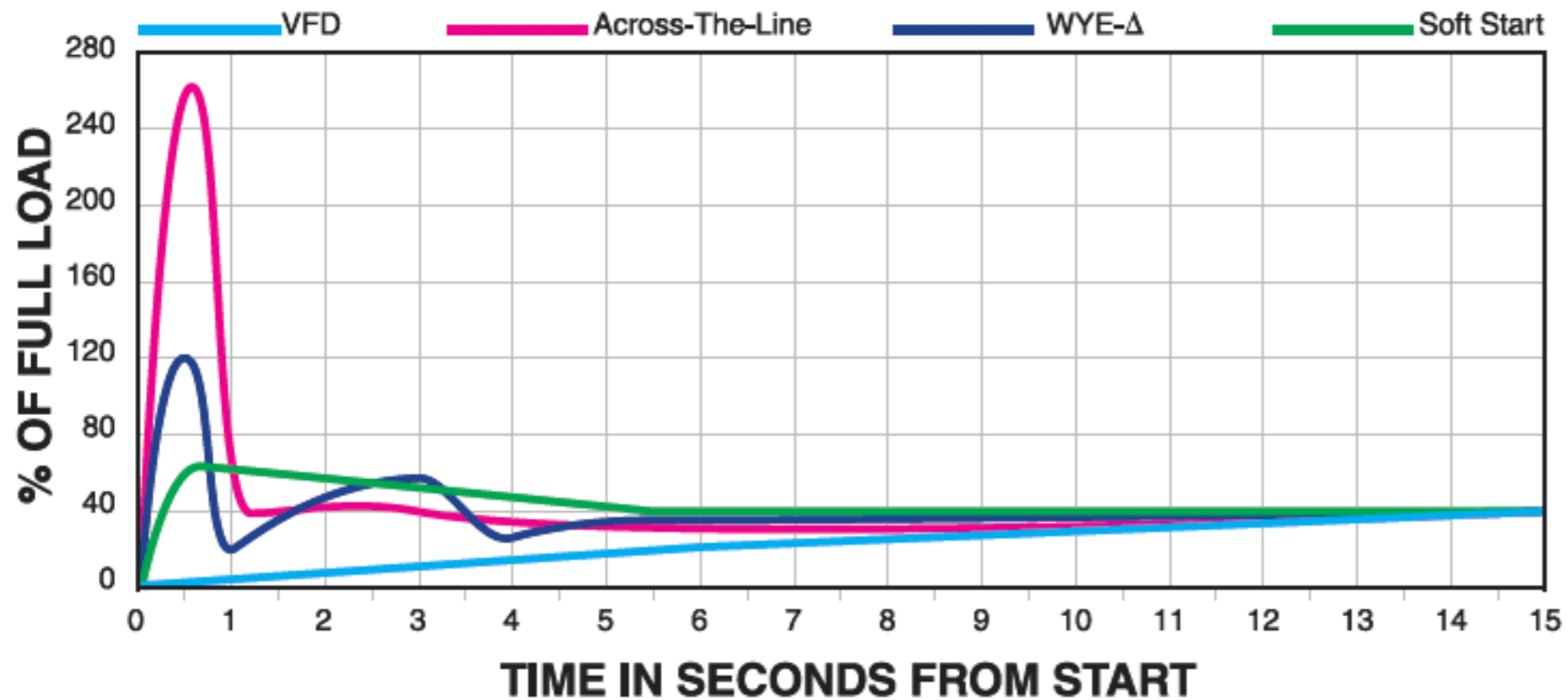
- Overvoltage/Undervoltage Protection
- Phase Loss Protection
- Overcurrent protection
- Short Circuit Protection

## Variable Frequency Drives

A Solid State Motor Control Device that can vary the speed and torque of an AC motor.

## START UP IN-RUSH CURRENT

(with 15 second unloaded start timer)



## In-rush Start up Current

Variable Frequency Drives can eliminate the in-rush start up current.

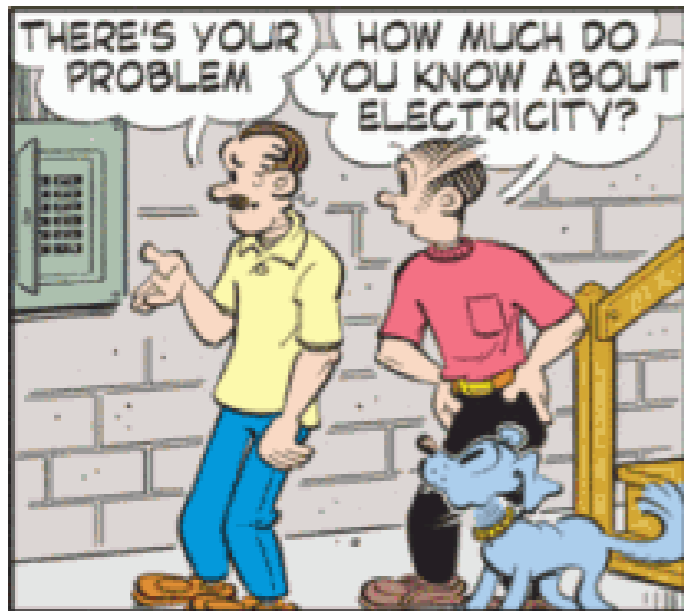


A **motor soft starter** is a device used with AC electric motors to temporarily reduce the load and torque in the powertrain and electrical current surge of the motor during startup. This reduces the mechanical stress on the motor and shaft, as well as the electrodynamic stresses on the attached power cables and electrical distribution network, extending the lifespan of the system. A Soft Start does not vary the speed of the motor as a VFD does.

## Soft Starters

Can be an inclusive solid state device, or added to an across the line starter

# Safety



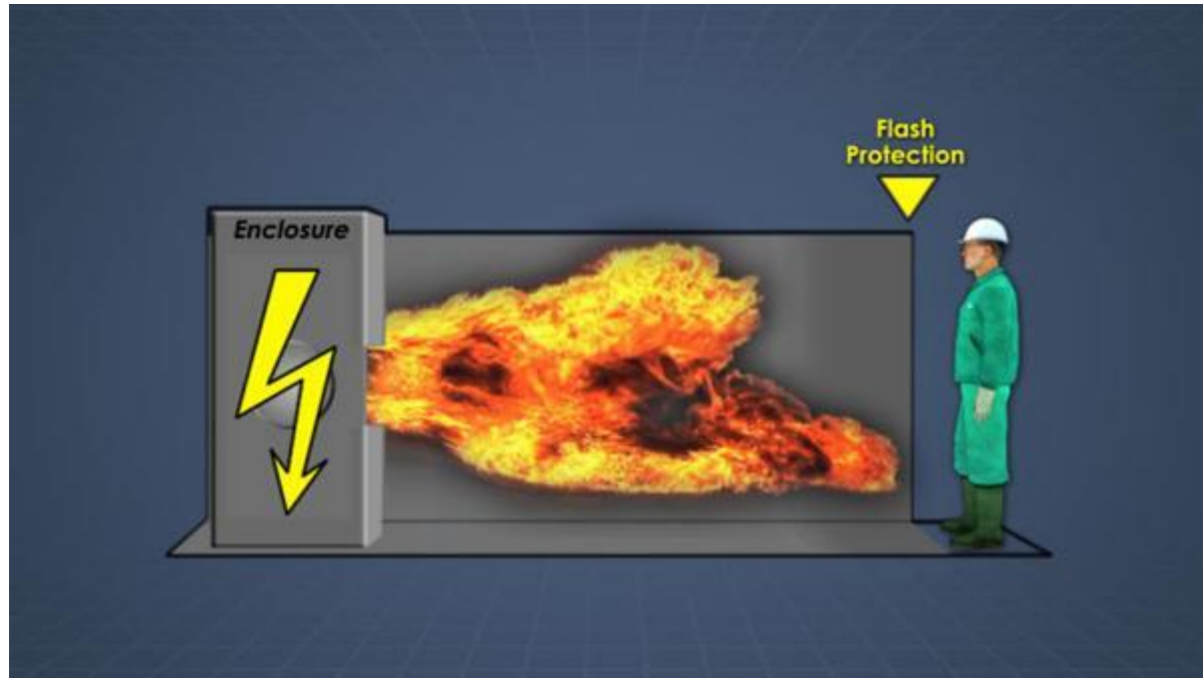


# Lock Out / Tag Out

Every facility should have a Lock Out / Tag Out procedure in place.

... And it should be enforced

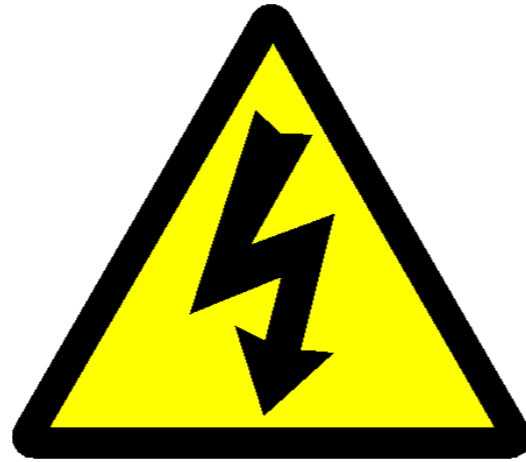
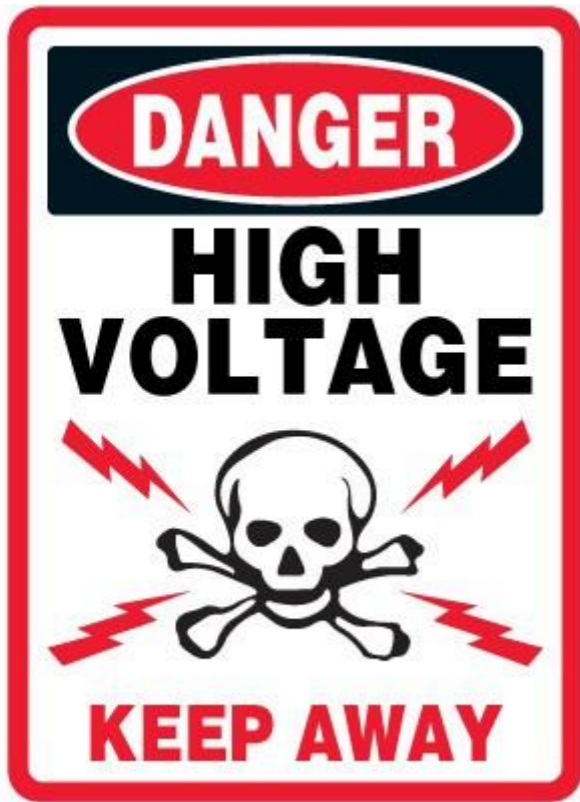





# Arc Flash Hazard

Never work on Live equipment... period



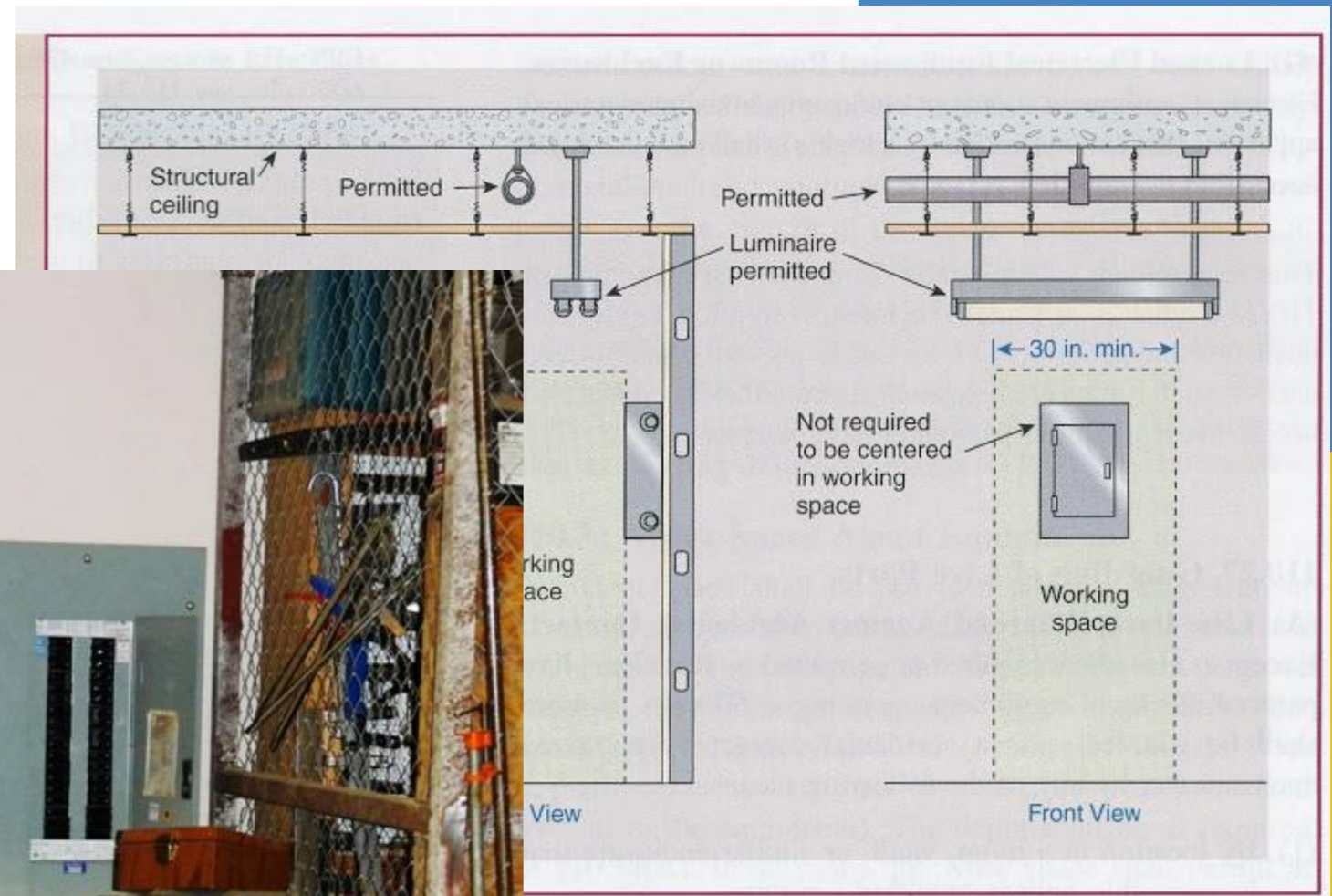


**DANGER**  
  
**LOW VOLTAGE  
DOES NOT MEAN  
LOW HAZARD.**  
**Work Safely!**



**Properly Marked Equipment**

**CAUTION**  
**OSHA REGULATIONS**  
**AREA IN FRONT OF**  
**ELECTRICAL**  
**PANEL**  
**MUST BE**  
**KEPT CLEAR**  
**FOR 36 INCHES**



# Electrical Equipment Clearance



# Thank you for your Attention!!

Hope you've  
learned  
something here  
today

Scott  
Fausneaucht



The Operator Training Committee of Ohio, Inc.

