A REVIEW

BASIC ELECTRICITY
AND
MAGNETISM ELECTRICITY

Prepared by

The Late Cecil Beggs
and
Mark Thomas

Revised and Edited by
Jim Allison

BASIC ELECTRICITY AND MAGNETISM ELECTRICITY

Voltage (electromotive force) - the electrical pressure that causes or forces current to flow through a conductor. Voltage may be compared to the pressure that causes water to flow in a pipe. Unit of measure is the volt. Symbol is V, E, v, e.

Current - the rate of flow of electrons through a conductor. Similar to the amount water, which flows through a pipe in a given time. Unit of measure is the ampere. Symbol is I, i.

Resistance - opposition to the flow of current through a conductor sometimes called electrical friction. Similar to the restricting of the flow of water in a pipe because of the pipe size. Unit of measure is the ohm. Symbol is R, r,Ω.

Ohm's Law - basic law in electricity, which says that one-volt, will cause one ampere of current to flow through one ohm of resistance. The formula is

$$E = I \times R \text{ or } I = E/R \text{ or } R = E/I$$

Example:

I_{in} = 5 amp

E

12 Ω
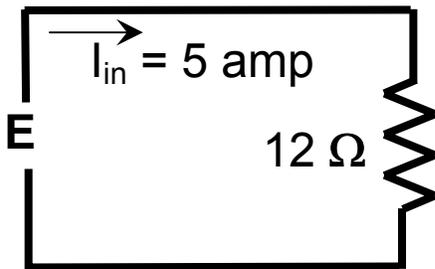
I = 5 amp
R = 5 Ω
Then
E = I x R
E = 5 x 12
E = 60 volts

Direct Current - an electric current where magnitude and direction remains the same with time.

Alternating Current - an electric current which moves first in one direction for a fixed period of time and then in the opposite direction for the same period of time. The current changes from 0 to a maximum positive value to 0 to a maximum negative value and back to 0 over a fixed period of time called "cycle." Basic alternating current changes 120 times a second or 60 complete changes per second. This is 60-cycle frequency.

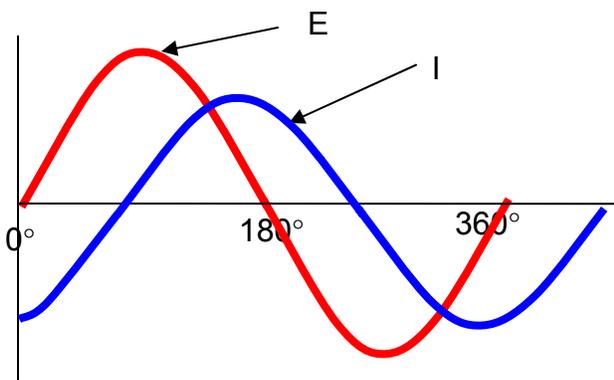
0°   180°   360°   I

1 Cycle
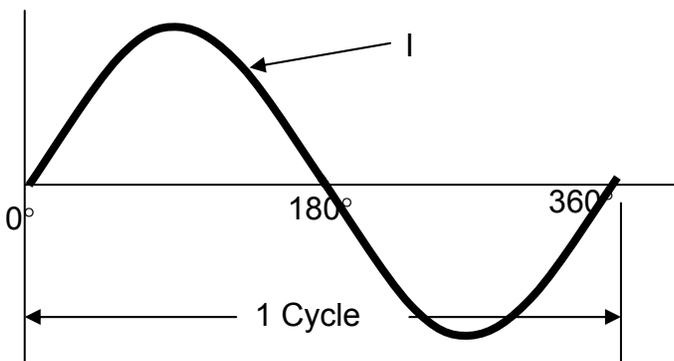
Power - is the rate of use of electric energy. An electric motor requires a certain amount of electric power to do a particular amount of mechanical work during a time period. Unit of measure is the watt. Symbol is P, p.

Direct Current - Power in d-c circuits is equal to volts times amperes, or, P = E X I.

By substituting Ohm's Law, power is also equal to $P = E \times I = (I \times R) \times I = I^2 R$ or
$P = E \times I = E \times (E/R) = E^2/R$

Alternating Current - Power in a-c circuits is not the same as power in d-c circuits because the total current can lag the voltage by a number of degrees. How much the current lags the voltage depends on the amount of inductive reactance in the circuit. Inductive reactance is similar to resistance; that is it is opposition to the flow of current, but unlike resistance, it causes the circuit current to lag the circuit voltage. When current lags voltage, it is out of phase with the voltage and may be shown as follows:

We may say there are two currents making up the total current required by induction motors, transformers and other induction devices in a-c circuits. There is power-producing current, I_P, and magnetizing current, I_M. Power- producing current is converted into useful work. Magnetizing current (wattles, reactive, wasted) non-working current is required to produce magnetic fields for induction devices. The relation between these currents is shown below.

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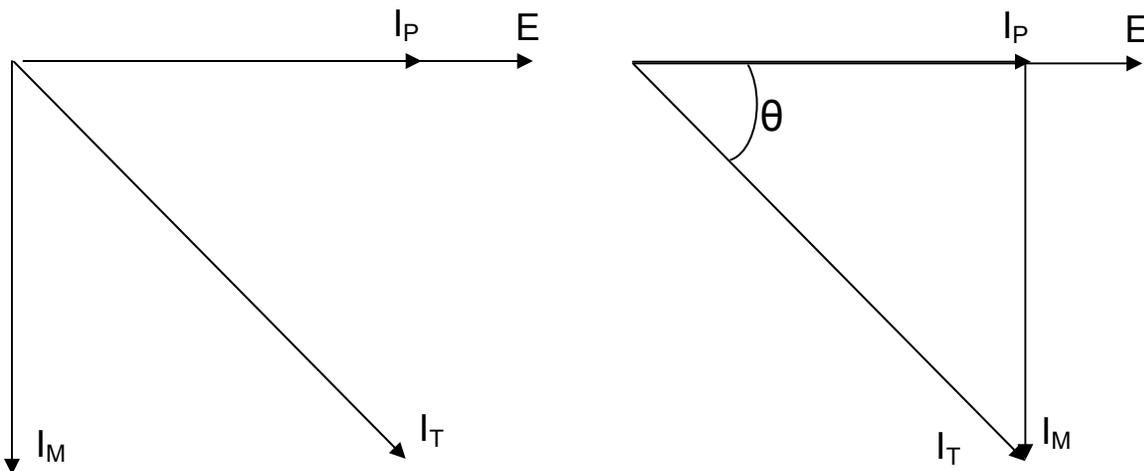
The total current, I_T is lagged θ from the voltage. Solving the above triangle, we obtain

$$\text{Cos } θ = I_P/I_T \text{ or } I_P = I_T \text{ Cos } θ$$

Power for d-c circuits was voltage times current, and the voltage and current was always is phase. For a-c circuits, where I_T is the current measured by an ammeter, we can substitute as follows:

$$P_{AC} = EI_P = EI_T \text{ Cos } θ$$

The Cos θ or the cosine of the angle by which the current lags the voltage is the power factor," designated as pf.

In review, we have said that for a-c circuits where the load causes the current to lag the voltage, the generated power or useful work is equal to El Cos θ in a-c circuits, the "apparent power" is the product El or volt-amperes. If an a-c load is pure resistance, the watts are equal to the volt-amperes and the Cos θ is 1 (θ = 0°). The "real power" or useful power, measured by the meter is the product El Cos θ or watts. As stated above, real power is equal to apparent power only when the Cos θ = 1 or θ = 0°. At all lagging power factors, where θ is greater than 0°, real power (watts) is less than apparent power. A third term for power in a-c circuits is reactive power or reactive volt-amperes (designated vars). Reactive power is the product El Sin θ and is present because of the magnetizing current required as discussed earlier. When Cos θ = 1, no vars are present is the circuit and the load is pure resistance.

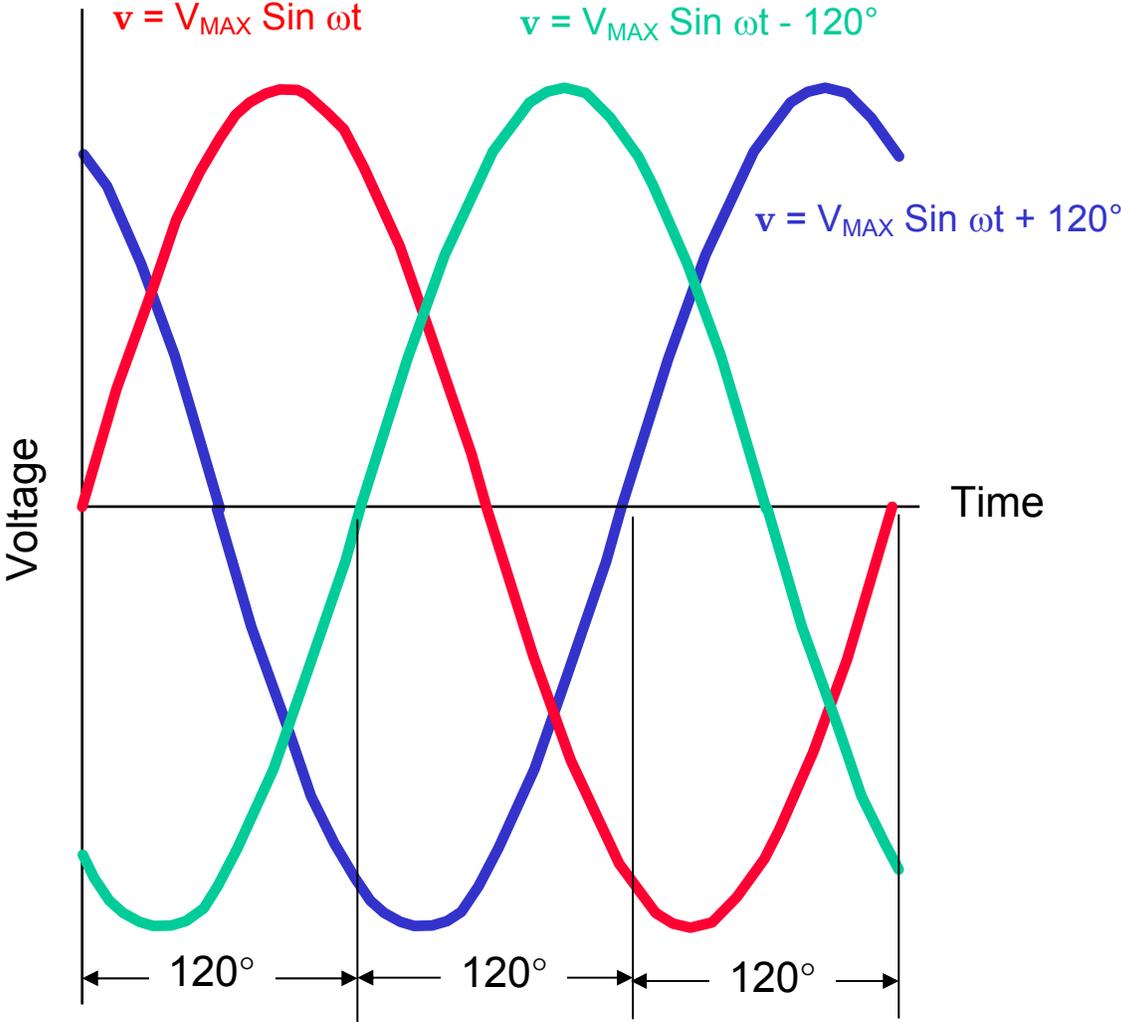These power terms may be related to one another as follows:

Voltamperes (El)

Vars (El Sin θ)

(Pf angle)

θ

Watts (El Cos θ)
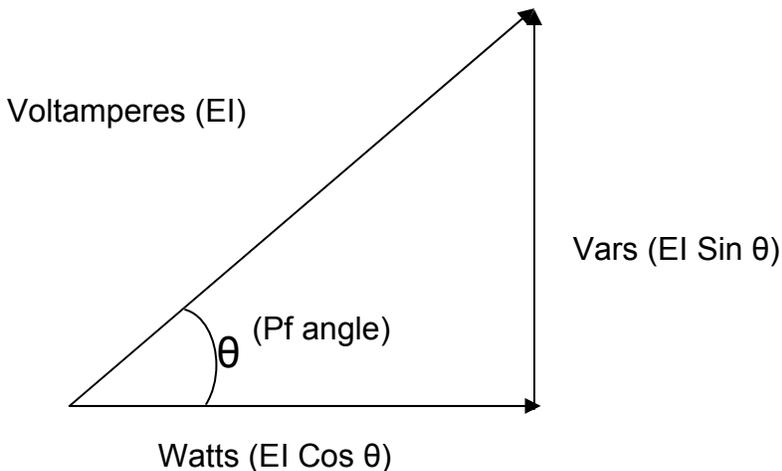
From the diagram at left, we see that
Cos θ = Watts/El
or
pf=Watts/EL

Sin θ = Vars/El.

If certain parameters are known, other parameters can be found by using these equations.

Three Phase

In a three-phase circuit there are three ungrounded inputs, and in some cases there is a neutral. There exist a voltage between the three inputs, each of these three is at the same frequency, has the same magnitude and are separated in time by 120°, as shown below.

$v = V_{MAX} \sin \omega t$

$v = V_{MAX} \sin \omega t - 120°$

$v = V_{MAX} \sin \omega t + 120°$

Voltage

Time

←— 120° —→ ←— 120° —→ ←— 120° —→

These three voltages can be applied to load in two ways, as a Delta or a Wye, as shown below.

Delta

Wye
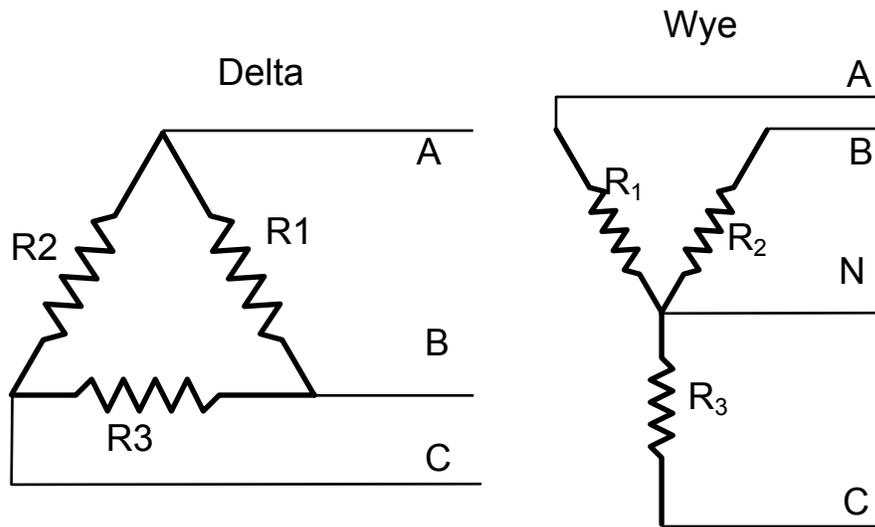
When we look at these configurations we see that the voltages and currents are not as straight forward as in single-phase.

In the Delta the phase voltage, the voltage across a load, is the same as the line-to-line voltage. However the line current is not equal to the phase current.
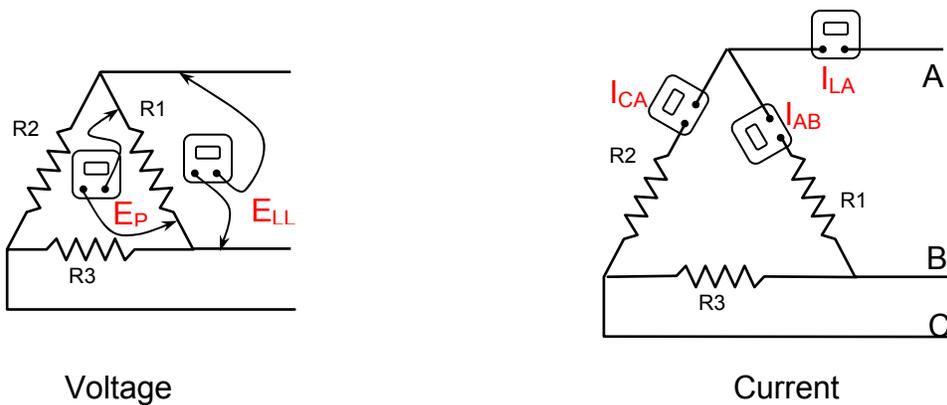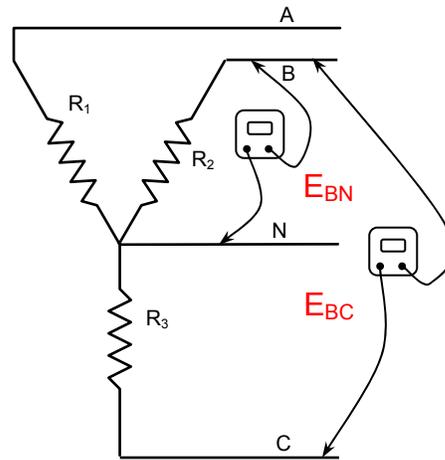

Voltage

Current

We see that the line current I_A is equal to the sum of I_{AB} plus I_{CA} .
For a Delta we can say:

$$\text{Voltage} \qquad E_{Line-Line} = E_{Phase}$$

$$\text{Current} \qquad I_{LA} = I_{AB} - I_{CA} \quad \text{then for a Delta} \qquad I_{Line} = 1.732 \, I_{Phase}$$

In the Wye the phase current, the current through the load, is the same as the line current. However the line-to-line voltage is not equal to the phase voltage.
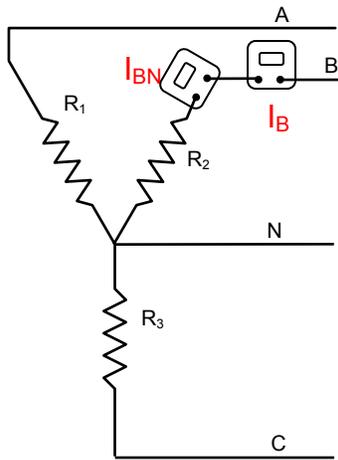
Current   Voltage

We see that the line current I_B is equal to I_{BN}.
For a Wye we can say:

$$\text{Current} \quad\quad I_{Line\text{-}Line} = I_{Phase}$$

Voltage $E_{AC} = E_{AN} - E_{NC}$ For balanced or grounded Wye $E_{Line} = 1.732\, E_{Phase}$

As you will remember that for a 208/120 Wye the voltages between the lines from the source is 208 volts, while that between a line and the neutral is 120 volts.

Over all we can summarize three phase as in the following table.

Type Circuit	Voltage	Current	Power
Delta	$E_{line} = E_{phase}$	$I_{line} = 1.732\, I_{phase}$	$P = 1.732\, E_{line}\, I_{line}\, Pf$
Wye	$E_{line} = 1.732\, E_{phase}$	$I_{line} = I_{phase}$	$P = 1.732\, E_{line}\, I_{line}\, Pf$

MAGNETISM

There are two classes of magnetic material. One is the hard or permanent magnets made from allows like Alnico (aluminum - nickel - cobalt) which once magnetized, retain a large part of their magnetism. The second class is soft magnets made from elements such as iron or nickel, which do not retain their magnetism after the magnetic field is removed. Materials such as glass, wood or copper are considered non-magnetic.

There are several principles of magnetism which include:

(1)   Magnets have north and south poles. If free to move, the North Pole would point toward the geographic North Pole.

(2)   Like poles (north-north or south-south) repel each other, while unlike poles (north-south or south-north) attract one another.

(3)   A pole's strength is measured by the force with which it will attract a magnetic object and depends on the pole's flux. Flux is magnetic lines, which come out of the North Pole and go into the South Pole. The more magnetic lines or flux per square inch of pole area, the stronger the magnet. This flux or magnetic lines around a magnet is called a magnetic field.
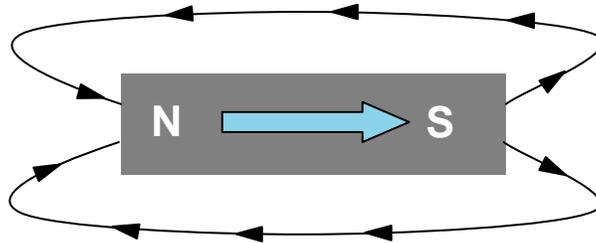

Both electricity and magnetism are used in the operation of a watt-hour meter. A straight conductor, such as a piece of wire, carrying a current is surrounded by a magnetic field. The direction of the field depends on the direction of the current.

If a long piece of wire is formed into a long coil, a north and south pole is established. If the wire were wrapped around a bar of soft iron, an electromagnet is made. An electromagnet is more useful than a permanent magnet because its strength can be changed by increasing the current. The polarity of the magnet can also be changed by reversing the current flow.

When the current flows in the winding, the core is magnetized, a magnetic flux is set up and a north and South Pole is established. The strength of the electromagnet depends on the current, the number of turns on the coil (ampere- turns) and the type of iron in the core.

One important fact is that increasing the current will increase the magnet strength only to a certain point. At this point, the iron core is saturated and the - magnetic strength of the iron core will no longer increase as the current is increased.
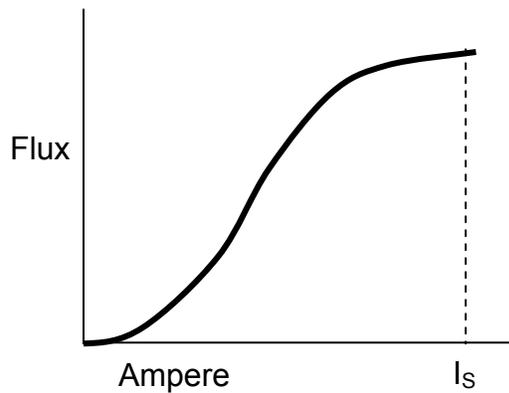
In the figure above, it is shown that for currents greater than I_S, the core is saturated and the magnetic strength flux remains essentially constant as the current is increased.

Just as an electric current will produce a magnetic field around a conductor, the reverse in which a magnetic field produces a current may also occur. If a wire is held in the field of magnet, then suddenly pulled out of the field, a voltage is induced in the wire. If the wire is a complete loop, a current will flow limited by the resistance of the loop. This is called induced current. The amount of induced voltage depends on the strength of the magnetic field and the speed of the conductor's motion across the flux lines.

In an a-c circuit, the induced voltage above opposes the applied voltage of the circuit and, therefore, causes the current that the applied voltage is trying to - push through the circuit to lag the applied voltage. This effect is inductive reactance (designated X1). How much the current lags the voltage depends on both the resistance and the reactance of the circuit. These two components result - in the impedance (symbol Z, measured in ohms) and may be shown as follows:
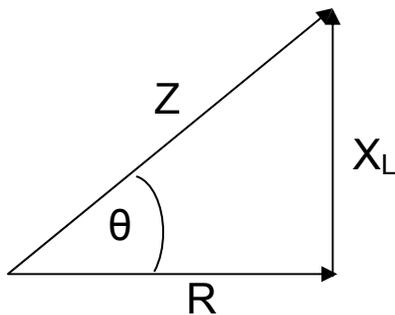
X_L = inductive reactance
R = resistance
Z = impedance

From the above, Cos θ = Z. Since this is the factor, which causes the current to lag the voltage, this Cos θ is also the power factor of the system.

Ohm's Law for a-c circuits now becomes E = IZ since Z in an a-c circuit is similar to the resistance in a d-c circuit.

SERIES CIRCUITS

Rule 1: The total current in a series circuit is equal to the current in any other par of the circuit.

$$\text{Total Current} = I_1 = I_2 = I_3 \text{ and etc.}$$

Rule 2: Total voltage in a series circuit is equal to the sum of the voltages across all parts of the circuit.

$$\text{Total Voltage} = E_1 + E_2 + E_3 \text{ and etc.}$$

Rule 3: Total resistance of a series circuit is equal to the sum of the resistances of all the parts of it.

$$\text{Total Resistance} = R_1 + R_2 + R_3 \text{ and etc.}$$

Amperes = $\dfrac{\text{Volts}}{\text{Resistance}}$

Resistance = $\dfrac{\text{Volts}}{\text{Amperes}}$

Volts = Amperes x Resistance

PARALLEL CIRCUIT'S

Rule 1: Total current in a parallel circuit is equal to the sum of the currents in all the branches of circuit.

Rule 2: Total voltage across any branch in parallel is equal to the voltage across - any other branch and is also equal to the total voltage.

$$\text{Total Voltage} = E_1 = E_2 = E_3 \text{ and etc.}$$

Rule 3: Total resistance in a parallel circuit is found by applying Ohms Law to that total values of the circuit.

Total Resistance = $\dfrac{\text{Total Voltage}}{\text{Total Amperes}}$

To determine the total resistance in a parallel circuit when the total current, and total voltage are unknown use either of the following formulas:

$$1/R_T = 1/R_1 + 1/R_2 + 1/R_3 + \ldots$$

$$R_T = (R_1 \times R_2)/(R_1 + R_2)$$

BASIC ELECTRICITY DEFINITIONS

Ammeter

An instrument to measure current flow, usually indicating in terms of amperes. Where indication is in milliamperes the instrument may be called a milliammeter.

Ampere

The practical unit of electric current. It is the current caused to flow through a resistance of one ohm by one volt.

Autotransformer

A transformer in which a part of the winding is common to both the input and output - circuits. Thus there is no electric isolation between input and output as in the usual transformer. Because of this interconnection, care must be exercised in using autotransformers.

Balanced Load

The term balanced load is used to indicate that there are substantially equal currents in all phase wires and substantially equal voltages between phase wires and between each - phase wire and neutral (if one exists), and substantially equal watts in each phase of the load.

Capacitance

That property of an electric circuit which allows storage of energy and exists whenever two conductors are in close proximity but separated by an insulator or dielectric material] When direct-current potential is impressed on the conductors a current flows momentarily while energy is being stored in the dielectric material, but stops when electrical equilibrium is reached. With an alternating potential between the conductors, the capacitive energy is transferred to and from the dielectric material, resulting in an alternating-current flow in the circuit.

Centi

A prefix meaning one-hundredth part of a specified unit.

100 centimeters = 1 meter

Circuit. Three-Wire

A metallic circuit formed by three conductors insulated from each other. See Three Wire System.

Circuit Breaker

A device, other than a fuse, designed to open a circuit when an overload or a short circuit occurs. The circuit breaker may be reset after the conditions, which caused the breaker to open, have been corrected.

Circular Mill

The area of a circle whose diameter is one mil (1/1000 in.). It is a unit of area equal to or 0.7854 square mil. The area of a circle in circular mils is; therefore, equal to the square of its diameter in mils.

Clockwise Motion

Rotation in the same direction as that of the hands of a clock, front view.

Connected Load

The sum of the continuous ratings of the connected load-consuming apparatus.

Copper Losses

The watts consumed in the wires, or conductors, of an electric circuit. Such power only heats the wires, doing no useful work, so it is a loss. It may be calculated from ~ where I is the conductor current and R is the resistance of the conductor.

Core Losses

Core losses usually refer to a transformer and are the watts requires in the excitation circuit to supply the heating in the core. Core heating is caused by magnetic hysteresis, condition which occurs when iron is magnetized with alternating current, and by the eddy currents flowing in~ the iron. Core losses are often called iron losses.

Cut-Out

A means of disconnecting an electric circuit. The cut-out generally consists of a fuse block and latching device, or switch.

Cycle

A cycle of an alternating current or voltage is one complete set of positive and negative values of the current or voltage. These values repeat themselves at regular intervals.

Demand

The term "demand" most commonly refers to the rate at which energy is consumed.

Eddy Currents (Foucault currents)

Those currents resulting from voltages which are induced in a conducting material by a variation of magnetic flux through the material.

Effective Resistance

Effective resistance is equal to watts divided by the square of the effective value of current.

Effective Value (Root-Mean-Square Value)

The effective value, of a periodic quality is the square root of the average of the square of the instantaneous values of the quality taken throughout one period. This value is also called the "root-mean-square" (rms) value and is the value normally indicated by alternating current instruments.

Electromagnet

A magnet in which the magnetic field is produced by an electric current. A common form of electromagnet is a coil of wire wound on a laminated iron core, such as the potential element of a watt-hour meter.

Electromotive Force (emf)

The force, which tends to produce an electric current in a circuit. The common unit of electromotive force is the volt.

Farad

The practical unit of capacitance. The common unit of capacitance is the microfarad.

Field. Magnetic

A region of magnetic influence surrounding a magnet or a conductor carrying electric current.

Galvanometer

An instrument for indicating a small electric current.

Ground

A conducting connection, whether intentional or accidental, between an electric circuit or equipment and earth.

Ground Return Circuit

A circuit in which the earth is utilized to complete the circuit.

Grounding Conductor

A conductor used to connect any equipment, device, or wiring system with a grounding electrode or electrodes.

Grounding Electrode

A conductor embedded in the earth, used for maintaining ground potential on conductors connected to it and for dissipating into the earth current conducted to it.

Henry

The practical unit of inductance. The millihenry is commonly encountered.

Horsepower

A commercial unit of power equal to the average rate of doing work when 33,000 pounds are raised one foot in one minute. One horsepower is approximately equal to 746 watts.

Impedance

The total opposing -effect to the flow of current in an alternating current circuit. It may - be determined in ohms from the effective value of total circuit voltage divided by the effective value of total circuit current. Impedance may consist of resistance or resistance - and reactance.

Induced Current

Correctly, we have only induced electromotive force in a conductor produced by changing the number of lines of magnetic force linking the conductor. If the conductor forms a closed circuit, a current flow results from the induced emf.

Inductance

That property of an electric circuit, which opposes any change of current through the circuit. In a direct-current circuit, where current does not change, there is no inductive -

effect except at the instant of turn-on and turn-off, but in alternating-current circuits the current is constantly changing so the inductive effect is appreciable. Changing current produces changing flux, which, in turn, produces induced voltage. The induced voltage opposes the change in applied voltage, hence the opposition to the change in current. Since the current changes more rapidly with increasing frequency, the inductive effect also increases with frequency.

Inductance Self

If the preceding effect occurs in the same conductor as that carrying the current, we have self-inductance. The self inductance of a straight conductor at power frequency is almost negligible because the changing flux will not induce any appreciable voltage, but self inductance increases rapidly if the conductor is in the form of a coil and more so if the coil is wound on iron.

Inductance. Mutual

If the current change causes an induced voltage and opposing effect in a second conductor we have mutual inductance.

Inductive

Having inductance, e.g., inductive current, inductive load. (Circuits containing iron or steel that is magnetized by the passage of current are highly inductive).

Inductive Reactance

Reactance due to inductance. This is expressed in ohms. The inductive reactance varies directly with the frequency.

Joule's Law

The rate at which heat is produced in an electric circuit of constant resistance is proportional to the square of the current.

Kilo

A prefix meaning one thousand of a specified unit (kilovolt, kilowatt).
1000 watts = 1 kilowatt.

KVA

The common abbreviation for kilovolt-ampere (equal to 1000 volt-amperes).

Lagging Current

An alternating current which, in each cycle, reaches its maximum positive value a fraction of a cycle later than the maximum positive value of the voltage which produces it.

Laminated Core

An iron core composed of sheets stacked in planes parallel to its magnetic flux paths in order to minimize eddy currents.

Leading Current

An alternating current which, in each cycle, reaches its maximum positive value a fraction of a cycle sooner that the maximum positive value of the voltage which produces it.

Magnetomotive Force

The force which produces magnetic flux. The magnetomotive force resulting from a current is directly proportional to the current.

Mega

A prefix meaning one million of a specified unit (mega-watt, megohm)
1,000,000 ohms = 1 megohm

Micro

A prefix meaning one-millionth part of a specified unit (microfarad, microhm).
1 ohm = 1,000,000 microhms

Mil
A unit of length equal to one one-thousandth of an inch.

Milli

A prefix meaning one-thousandth part of a specified unit (milliampere, millihenry, millivolt).   1 volt = 1,000 millivolts

Ohm

The practical unit of electric resistance. It is the resistance which allows one ampere to flow when the impressed potential is one volt.

Ohm's Law

Ohm's Law states that the current which flows in an electric circuit is directly proportional to the electromotive force impressed on the circuit and inversely proportional to the resistance in a direct-current circuit or impedance in an alternating-current circuit. Formula: $E = I \times R$

Phase Angle

The phase angle or phase difference between a sinusoidal voltage and a sinusoidal current is defined as the number of electrical degrees between the beginning of the cycle of voltage and the beginning of the cycle of current.

Power Factor

The relationship between the active power and the volt-amperes in any particular alternating-current circuit. It is defined as the ratio of the total active power to the total volt-amperes, and is also numerically equal to the cosine of the angle of phase displacement between the total circuit voltage and current. Thus, in a circuit which is entirely resistive the power factor is 1, since we have only active power, or watts, and in this circuit the volt-amperes are equal to the watts. In a purely reactive circuit the power factor is 0 (cosine of 90 deg) since there are no watts and the volt-amperes consist of vars only. In circuits which are a mixture of both resistance and reactance, the most common type of circuit, the power factor has a value between 0 and 1, depending on the relative values of the circuit components.

Reactance

The measure of opposition to current flow in an electric circuit caused by the circuit properties of inductance and capacitance. Reactance is normally expressed in ohms.

Rectifier

A device which permits current to flow in one direction only, thus converting alternating current into unidirectional current.

Resistance

The opposition offered by a substance or body to the passage through it of an electric current. Resistance is the reciprocal of conductance.

Rheostat

An adjustable resistor so constructed that its resistance may be changed without opening the circuit in which it is connected.

<u>Service Entrance Conductors</u>

For an overhead service, that portion of the service conductors which connect the service drop to the service equipment. The service entrance conductors for an underground service are that portion of the service conductors between the terminal box located on either the inside or outside building wall, or the point of entrance in the building if no terminal box is installed, and the service equipment.

<u>Service Equipment</u>

The necessary equipment, usually consisting of one or more circuit breakers or switches and fuses, and their accessories, intended to constitute the main control and means of disconnecting the load from the supply source.

<u>Short Circuit</u>

A fault in an electric circuit, instrument, or utilization equipment such that the current follows a low resistance by-path instead of its intended course.

<u>Thermocouple</u>

A pair of dissimilar conductors so joined that two junctions are formed. An electromotive force is developed by the thermoelectric effect when the two junctions are at different temperatures.

<u>Three-Wire System</u>

(direct-current, single-phase, or network alternating-current) A system of electric supply comprising three conductors, one of which (known as the "neutral wire" 0 is generally grounded and has the same approximate potential between it and either of the other two wires (referred to as the outer or "hot" conductors).

Note: Part of the load may be connected directly between the outer conductors, the remainder being divided as evenly as possible into two parts, each of which is connected between the neutral and one outer conductor.

<u>Transformer</u>

An electric device without moving parts which transfers energy from one circuit to one - or more other circuits by means of electromagnetic fields. The name implies, unless otherwise described, that there is complete electrical isolation among all windings of a - transformer, as contrasted to an autotransformer.

<u>Vars</u>

The term commonly used for volt-amperes reactive

Vector

A quantity which has both magnitude and direction. This quantity was used previously t represent alternating voltages and currents but has been replaced by the phaser.

Volt

The practical unit of electromotive force, or potential difference. One volt will cause one ampere to flow when impressed across a one-ohm resistor.

Volt-Ampere

Volt-amperes are the product of volts and the total current which flows because of the voltage. In d-c circuits and a-c circuits with unity power factor the volt-amperes and the watts are equal. In a-c circuits at other than unity power factor the volt-amperes equal the square root of watts squared plus reactive volt-amperes squared.

Watt

The practical unit of active power which is defined as the rate at which energy is delivered to a circuit. It is the power expanded when a current of one ampere flows through a resistance of one ohm.

Watthour

The practical unit of electric energy which is expended in one hour when the power is one watt.

Symbols

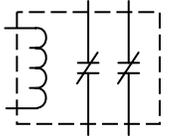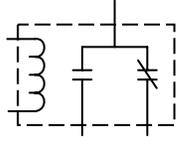|			
$	Switch	$₃	Three Way Switch
$₄	Four Way Switch	$_WP	Water proof Switch
⊖	Duplex Receptacle	⊖	Single Receptacle
⊖	Split Wired Receptacle	◑	Special Purpose Receptacle
⊖	Floor Receptacle	⊖	240 V Receptacle
⊖ GFCI	GFCI Receptacle	⌒	Circuit Breaker
▭	Fuse	▬▬▬	Power Cable
———	Control Cable	▬ ▬ ▬	Under Cable
▬ · ▬ · ▬	Concealed in Floor	➝	Home Run
⫽⫽⫽	Number of Conductors (4)	—•—	Connected
—⊢—	Not Connected	—⌐—	Not Connected
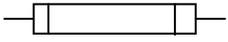
Controls
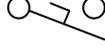
Limit Switch	Foot Switch
Vacuum Switch	Liquid Level
Timed Switch Energized	Timed Switch De-Energized
Temperature	Flow Switch
Momentary Contact NO	Momentary Contact NC
Mushroom Head NO	Double Break Switch
Selector Switch	Two Position Switch
Magnetic Starter Double Pole	Overload Protection
Single Pole Single Throw Relay SPST NO	Single Pole Single Throw Relay SPST NC
Double Pole Single Throw Relay DPST NO	Single Pole Double Throw Relay SPDT
Double Pole Double Throw Relay DPDT	Triple Pole Single Throw TPST
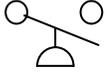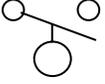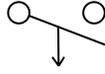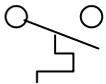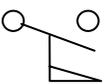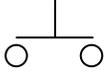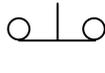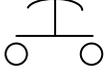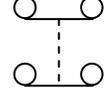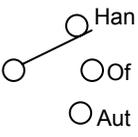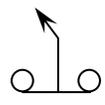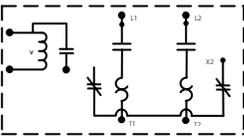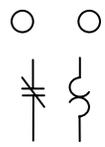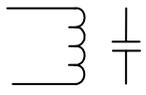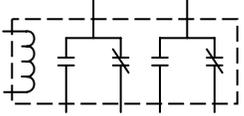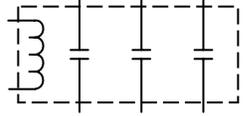
Equations

Ohms Law

$$E = IR, \quad I = \frac{E}{R}, \quad R = \frac{E}{I}$$

DC Power

$$P = EI, \quad P = I^2R, \quad P = \frac{E^2}{R}$$

AC Power

$$P = E \, I \, Pf$$

(Pf ranges from 0.0 to 1.0)

Current

$$I = \frac{E}{R}, \quad I = \frac{P}{E}, \quad I = \sqrt{\frac{P}{R}}$$

Resistance

$$R = \frac{E}{I}, \quad R = \frac{E^2}{P}, \quad R = \frac{P}{I^2}$$

Volts

$$E = IR, \quad E = \frac{P}{I}, \quad E = \sqrt{P \, R}$$

Series Circuits

Current

$$I_{IN} = I_1 = I_2 = I_n$$

Voltage

$$E_{in} = E_1 + E_2 + E_n$$

Resistance

$$R_{in} = R_1 + R_2 + R_n$$

Parallel Circuits

Current

$$I_{in} = I_1 + I_2 + I_n$$

Voltage

$$E_{IN} = E_1 = E_2 = E_n$$

Resistance (R)

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_n}$$

Or for two resistors

$$R_{eq} = \frac{R_1 \times R_2}{R_1 + R_2}$$

Or for a number(n) of resistors of the same size

$$R_{eq} = \frac{R}{n}$$

$$R = 20\,\Omega$$

$$n = 4$$

$$R_{eq} = \frac{20}{4}$$

$$R_{eq} = 5\,\Omega$$

Capacitors (C)

$$C = \frac{Q}{E} = \frac{Coulombs}{Volts}$$

C is measured in farads
1 Farad = 1,000,000 Microfarad

Capacitors in series add as Resistors in parallel

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_n}$$

Capacitors in parallel add as Resistors in series

$$C_{in} = C_1 + C_2 + C_n$$

Inductors (L)

L is measured in Henrys
1 Henry = 1,000 Millihenry
Inductors in series add as Resistors in series

$$L_{in} = L_1 + L_2 + L_n$$

Inductors in parallel add as Resistors in parallel

$$\frac{1}{L_{eq}} = \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_n}$$

Reactance (X)

Reactance in an AC circuit is the opposition caused by capacitors and inductance, expressed in ohms.

Capacitive reactance X_C
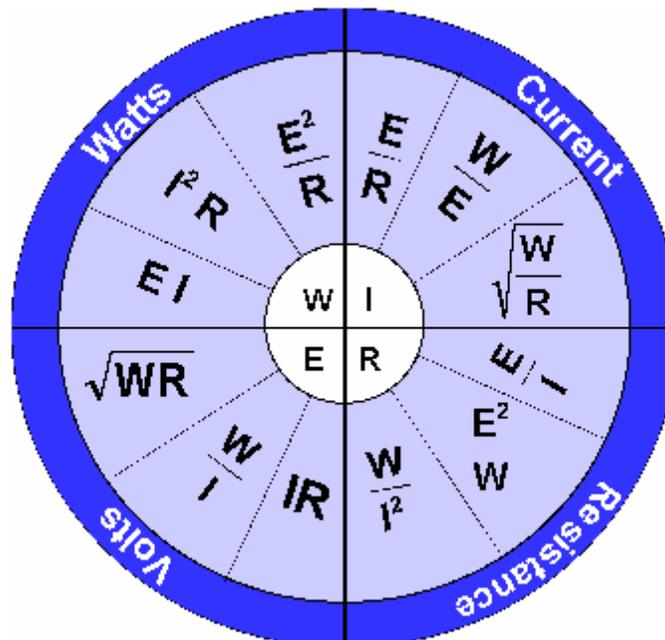
$$X_c = \frac{1}{2 \times 3.1416 \times F \times C}$$

Inductive Reactance X_L

$$X_L = 2 \times 3.1416 \times F \times L$$

Total Opposition
Containing resistors, capacitors, and inductors

$$Z = \sqrt{R^2 + j(X_L - X_c)^2}$$

Electrical Equations for Calculating Current, Power,
Apparent Power and Horsepower

To Find	Single Phase	Three Phase
Power – P – (Watts)	E x I x Pf	1.732 x E x I x Pf
Power - P – (Kilowatts)	$\dfrac{\text{E x I x Pf}}{1,000}$	$\dfrac{\text{1.732 x E x I x Pf}}{1,000}$
Apparent Power - VA	E x I	1.732 x E x I
Apparent Power – kVA	$\dfrac{\text{E x I}}{1,000}$	$\dfrac{\text{1.732 x E x I}}{1,000}$
Current when "kW" is Known	$\dfrac{\text{kW x 1,000}}{\text{E x Pf}}$	$\dfrac{\text{kW x 1,000}}{\text{E x Pf x 1.732}}$
Current when "kVA" is Known	$\dfrac{\text{kVA x 1,000}}{\text{E}}$	$\dfrac{\text{kVA x 1,000}}{\text{E x 1.732}}$
Horsepower - Hp	$\dfrac{\text{E x I x \% Eff x Pf}}{746}$	$\dfrac{\text{1.732 x E x I x \% Eff x Pf}}{746}$
Current when "Hp" is Known	$\dfrac{\text{746 x Hp}}{\text{E x \% Eff x Pf}}$	$\dfrac{\text{746 x Hp}}{\text{1.732 x E x \% Eff x Pf}}$
Percent Efficiency	$\dfrac{\text{Output}}{\text{Input}}$	
Power Factor	$\dfrac{\text{Power (watts)}}{\text{Apparent Power(VA)}}$	

Remember for three phase circuits there are two voltages and two currents,
$E_{\text{line to line}}$ *and* E_{phase} *as well as* I_{line} *and* I_{phase}.

For a Delta

$E_{\text{line to line}} = E_{\text{phase}}$

$I_{\text{line}} = \sqrt{3}\, I_{\text{phase}}$

For a Wye

$E_{\text{line to line}} = \sqrt{3}\, E_{\text{phase}}$

$I_{\text{line}} = I_{\text{phase}}$

For the above three phase equations the line values are to be used.

Voltage Drop Calculations

Single Phase Circuits -   Two and Three wire Circuits

$$V_D = \frac{2\rho \mathbf{x} L \mathbf{x} I}{Cm}$$
$$Cm = \frac{2\rho \mathbf{x} L \mathbf{x} I}{V_D}$$

Three Phase Circuits

$$V_D = \frac{\sqrt{3}\rho \mathbf{x} L \mathbf{x} I}{Cm}$$
$$Cm = \frac{\sqrt{3}\rho \mathbf{x} L \mathbf{x} I}{V_D}$$

Where:

V_D = Voltage Drop (Volts)
Cm = Cross-sectional Area (Circular Mils)
L = Length One-Way (Feet)
I = Current (Amperes)

ρ = Resistivity (Ohms-Circular mils/foot)
some times called K

ρ_{Copper} = 12.9 at 75°C

$\rho_{Aluminum}$ = 21.2 at 75°C

Always check ampacity in Table 310.15 of the National Electrical Code.

Using resistance listed in NEC Conductor Properties

Single Phase Circuits   -   Two and Three wire Circuits

$$V_D = \frac{2 \mathbf{x} I \mathbf{x} R \mathbf{x} L}{1,000}$$

Three Phase Circuits

$$V_D = \frac{\sqrt{3} \mathbf{x} I \mathbf{x} R \mathbf{x} L}{1,000}$$

Where:

I = Current (Amperes)
R = Resistance from Tables (Ohms/1,000 ft)
L = One-Way Length (Ft)

Synchronous speed of AC motors

$$Speed = \frac{Frequency \text{ x } 120}{No. \ Poles}$$