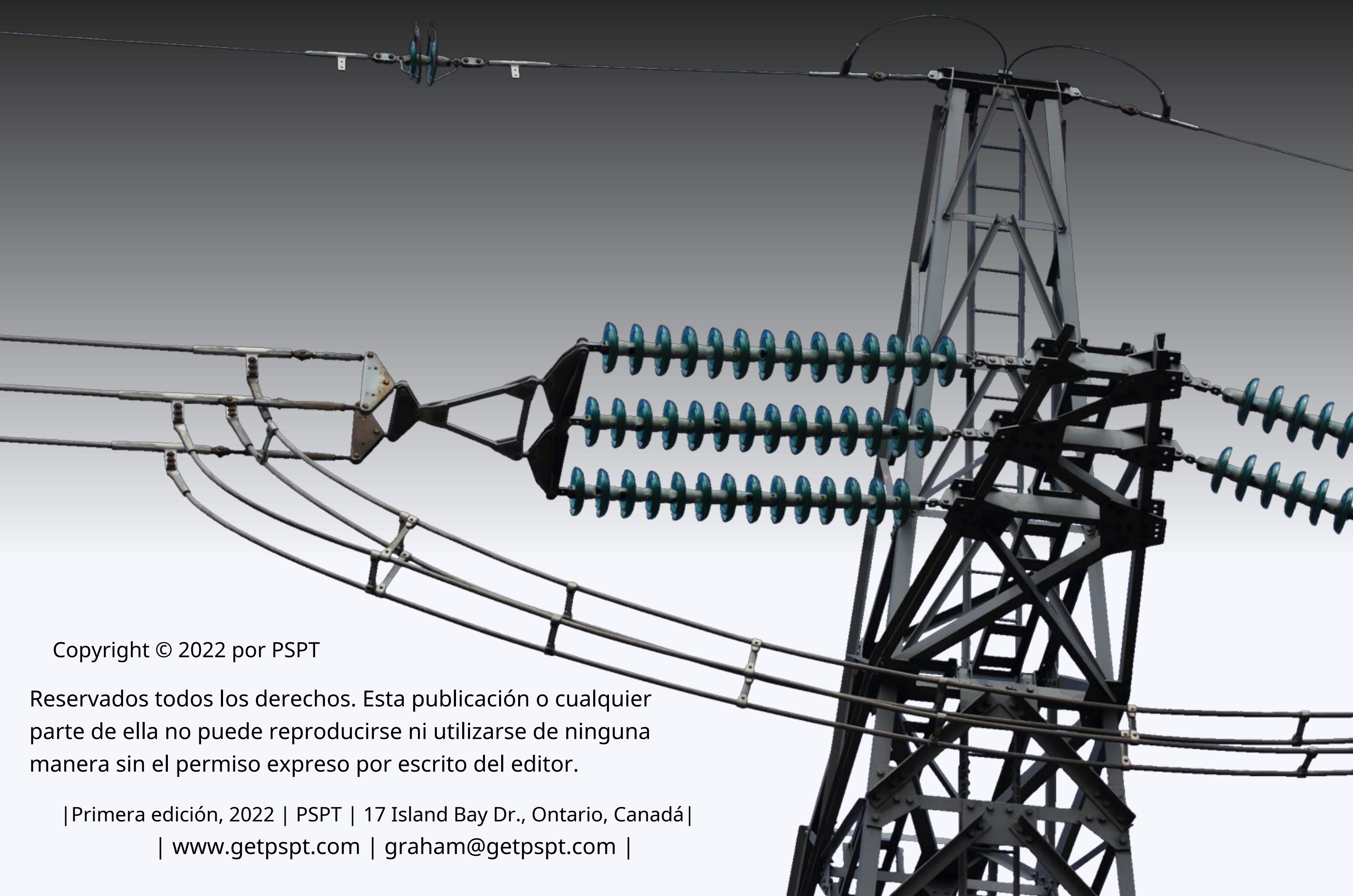
PSPT
Power Systems Protection Training

Energía eléctrica
Notas y fórmulas



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Índice

Las 14 secciones están numeradas individualmente.

1) Análisis del circuito CC

Ley de Ohm

Corriente, voltaje y resistencia

$$V = I R$$

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

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

Conductancia

$$G = \frac{1}{R} \quad \text{siemens}$$

$$G = \frac{I}{V}$$

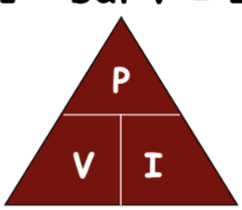
Energia electrica

1 culombio = 6,241 x 10^{18}electrones Trabajo realizado = Voltios x Q(carga) Julios Trabajo realizado = Voltios xI (amperios) Potencia en julios = Trabajo/tiempo (seg) Watts

$$P = \frac{W}{t} = VI \quad \text{but } V = IR$$

$$P = I^2R$$

$$P = \frac{V^2}{R}$$

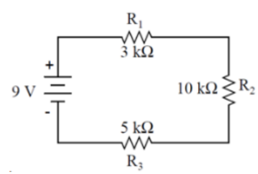


$$V = \frac{P}{I} \quad \text{Volts}$$

$$I = \frac{P}{V} \quad \text{Amps}$$

Múltiplos SI para vatios (W)						
Submúltiplos				Múltiplos		
Valor	Símbolo	Nombre		Valor	Símbolo	Nombre
10^{-1}W.	dw	decivatio		10^{1}W.	grajilla	decavatio
10^{-2}W.	cw	centivatios		10^{2}W.	hw	hectovatio
10^{-3}W.	**mW**	**milivatios**		10^{3}W.	**kilovatios**	**kilovatio**
10^{-6}W.	**μW**	**microvatio**		10^{6}W.	**megavatio**	**megavatio**
10^{-9}W.	**noroeste**	**nanovatio**		10^{9}W.	**G.W.**	**gigavatio**
10^{-12}W.	**pW**	**picovatio**		10^{12}W.	**tw**	**teravatio**
10^{-15}W.	fW	femtovatio		10^{15}W.	VP	petavatio
10^{-18}W.	aw	attovatio		10^{18}W.	EW	exavatio
10^{-21}W.	zW	zeptovatio		10^{21}W.	ZW	zettavatio
10^{-24}W.	yW	yoctovatio		10^{24}W.	YW	yottawatt
Los múltiplos comunes están en**atrevido**rostro						

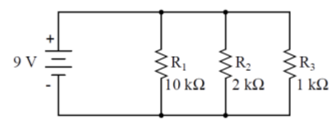
Circuitos en serie y paralelo



$$R_T = R_1 + R_2 + R_3$$

Ley de voltaje de Kirchhoff:

La suma de las caídas de potencial (caídas de voltaje) alrededor de cualquier circuito cerrado es cero



$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

Ley actual de Kirchhoff:

Todas las corrientes que entran en una nota suman cero

Corrientes que entran en "+"

Corrientes que salen de "-"

Teoremas del circuito

Propiedad de homogeneidad (escalado)

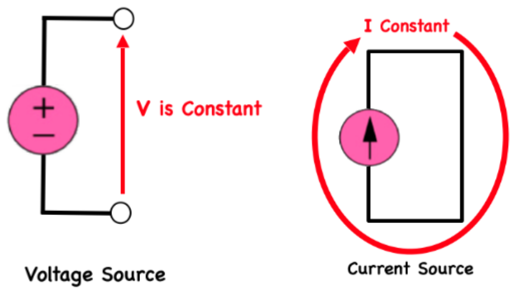
$$v = iR \rightarrow kv = kiR$$

Propiedad aditiva

$$\text{If } v_1 = i_1R \text{ and } v_2 = i_2R$$

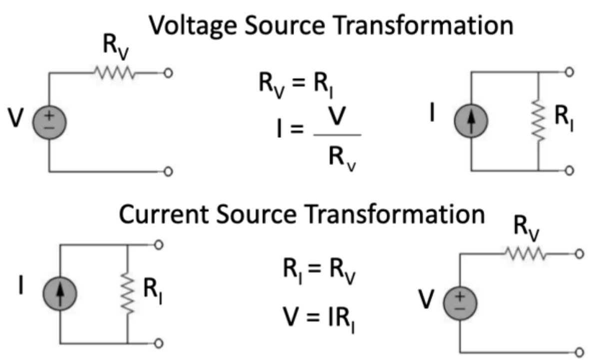
$$v_1 + v_2 = i_1R + i_2R = (i_1 + i_2)R$$

Fuentes de tensión y corriente.



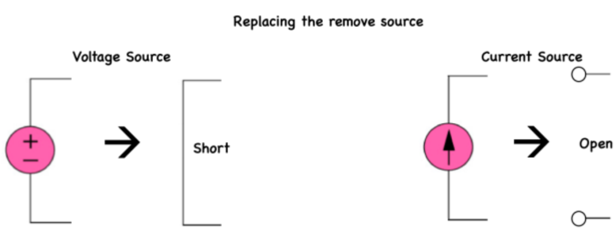
Transformación de fuente

La transformación de una fuente de energía de una fuente de voltaje a una fuente de corriente, o de una fuente de corriente a una fuente de voltaje.



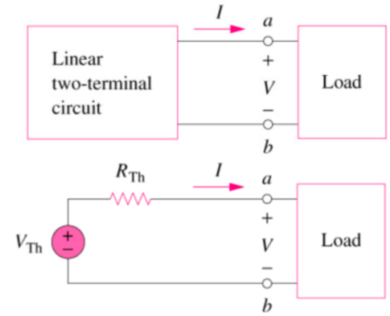
Teorema de superposición

En un circuito lineal con varias fuentes, la caída de corriente y tensión, para cualquier elemento del circuito, es la suma de las corrientes y tensiones producidas por cada fuente actuando de forma independiente.



Teorema de Thévenin

Un circuito lineal de dos terminales se puede reemplazar por un circuito equivalente que consta de una fuente de voltaje V_{TH} en serie con una resistencia R_{TH}

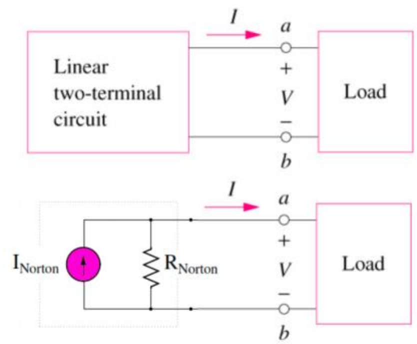


V_{Th} is the open-circuit voltage at the terminals

R_{Th} is the input or equivalent resistance at the terminals

Teorema de Norton

Un circuito lineal de dos terminales se puede reemplazar por un circuito equivalente que consta de una fuente de corriente. I_{norton}en paralelo con una resistencia R_{norton}



R_{Norton} is the input or equivalent resistance at the terminals

I_{Norton} is the current flowing in the shorted terminals

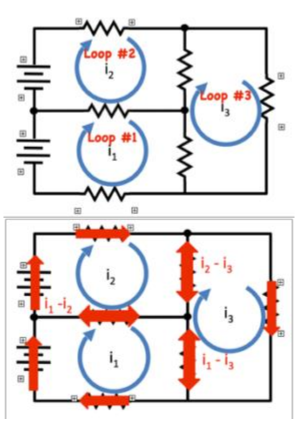
Análisis de corriente de malla (o bucle)

Now write the Kirchoff's Voltage Law equations for each loop:

Voltage drops are +'ve and across each resistor are given by Ohms Law V = I X R

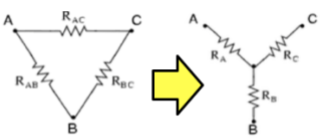
Voltage rises are -'ve and equal to the voltage source ratings

Voltage drops across common resistors (resistors with two currents flowing in them) are given by Ohms Law V = I X R and are +'ve (the polarity is according to the the loop current being followed).



The I in the Ohms Law equation (V = I X R) is the arithmetic sum of the two currents flowing through it. The loop current being followed is +'ve the other current is +'ve or -'ve depending on its direction flow with respect to the loop current being followed.

To convert from a Delta (Δ) to a Wye (Y)

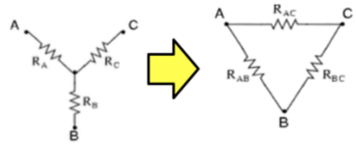


$$R_A = \frac{R_{AB}\,R_{AC}}{R_{AB}+R_{AC}+R_{BC}}$$

$$R_B = \frac{R_{AB}\,R_{BC}}{R_{AB}+R_{AC}+R_{BC}}$$

$$R_C = \frac{R_{AC}\,R_{BC}}{R_{AB}+R_{AC}+R_{BC}}$$

To convert from a Wye (Y) to a Delta (Δ)

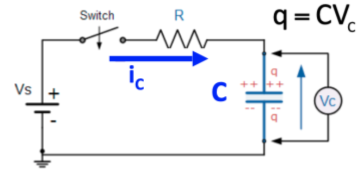


$$R_{AB} = \frac{R_A R_B + R_A R_C + R_B R_C}{R_C}$$

$$R_{BC} = \frac{R_A R_B + R_A R_C + R_B R_C}{R_A}$$

$$R_{AC} = \frac{R_A R_B + R_A R_C + R_B R_C}{R_B}$$

La ley de Ohm y un condensador

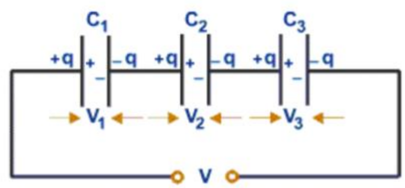


$$q = CV_c \qquad \frac{\Delta q}{\Delta t} = i = C\frac{\Delta V_c}{\Delta t}$$

$$i_c = C\frac{dV_c}{dt}$$

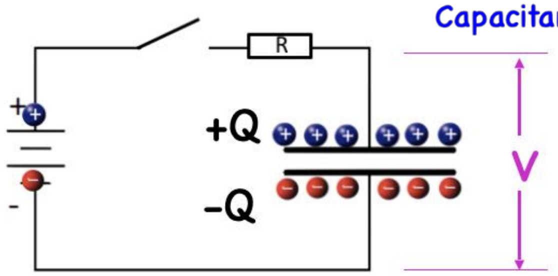
- V_c → instantaneous voltage on the Capacitor
- q → charge on the capacitor
- C → the capacitance of the capacitor
- Δq → The change in q → charge on the capacitor
- Δt → The change in time
- i_c → current to the capacitor

Capacitors in Series



$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

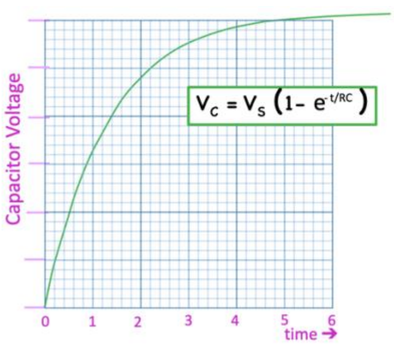
Campos eléctricos y C



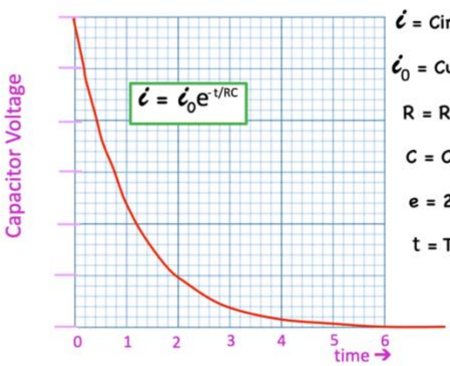
$$\text{Capacitance} = \frac{Q}{V}$$

$$Q = CV$$

Capacitance→farad (F)

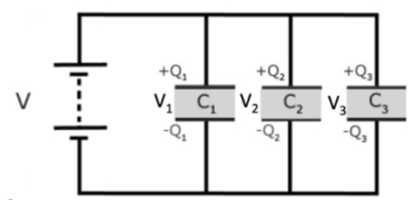


- V_C = charging voltage (Volts)
- V_S = Supply Voltage (Volts)
- R = Resistance (Ohms)
- C = Capacitance (Farads)
- e = 2.718281828
- t = Time (Seconds)



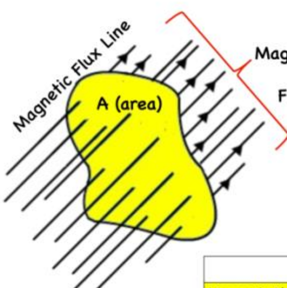
- i = Circuit Current (Amps)
- i_0 = Current at t = 0 (V_S/R Amps)
- R = Resistance (Ohms)
- C = Capacitance (Farads)
- e = 2.718281828
- t = Time (Seconds)

Capacitors in parallel



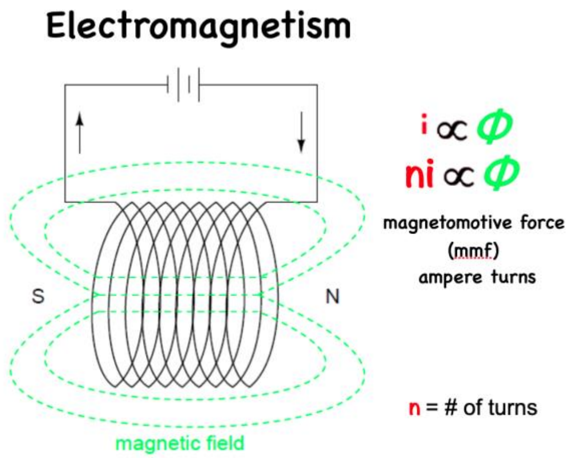
$$C_T = C_1 + C_2 + C_3$$

Magnetic Flux & Flux Density

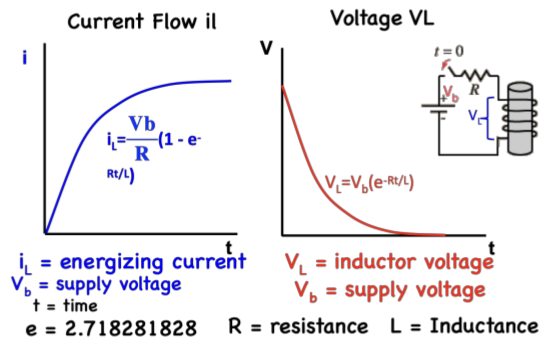


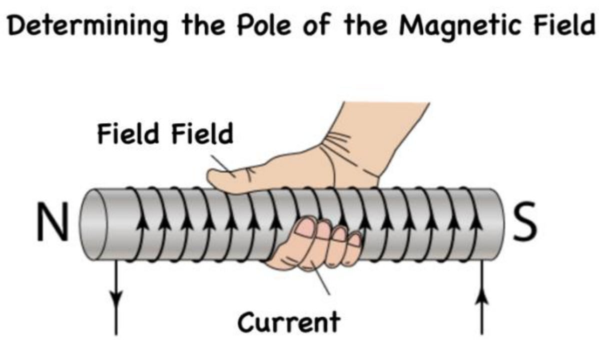
Flux Density $B = \frac{Ø}{A}$ T (tesla) Weber per Sq meter

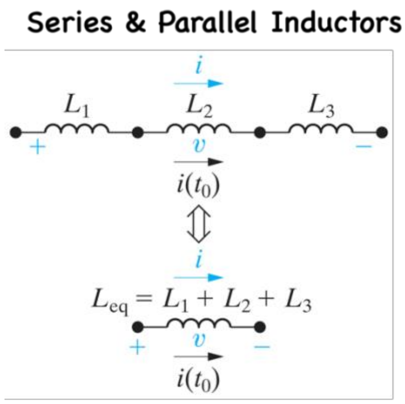
	Symbol	Unit
Magnetic Flux		Wb (Webers)
Magnetic Flux Density	**B**	T (tesla) Weber per Sq meter

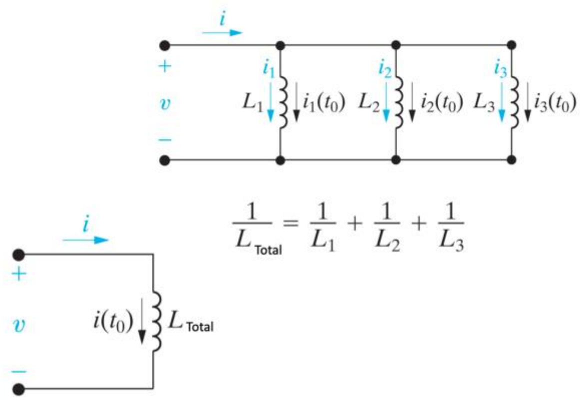


Energizar un inductor

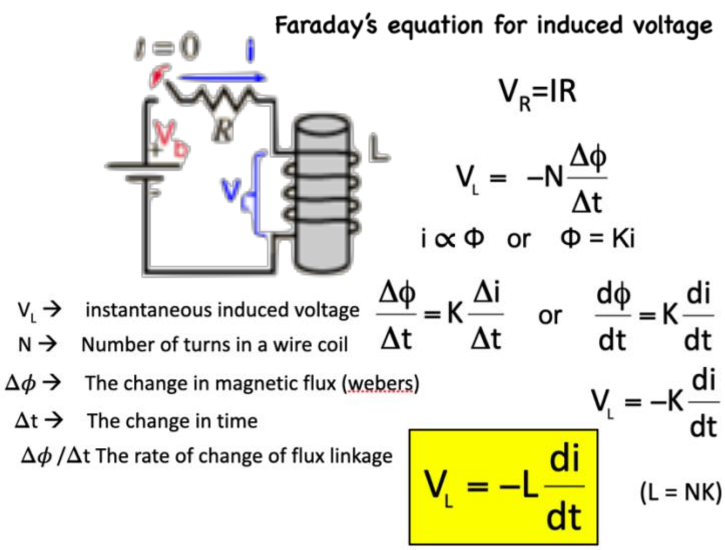






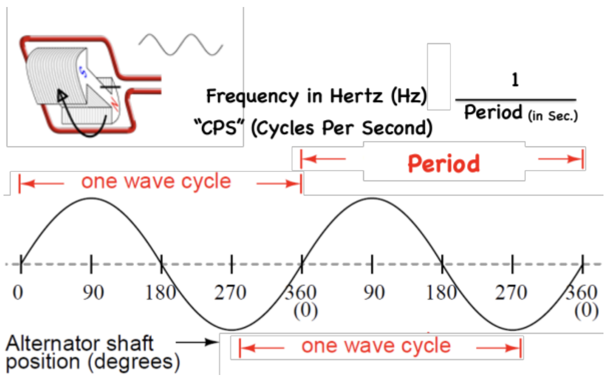


Inducción electromagnética



2) Análisis del circuito de CA

Ondas sinusoidales y valores RMS



The r.m.s. value of an a.c. supply is equal to the direct current which would dissipate energy at the same rate in a given resistor

We can use the same logic to define the r.m.s. value of the voltage of an alternating voltage supply.

$$V_{rms} = \frac{V_{max}}{\sqrt{2}} \qquad I_{rms} = \frac{I_{max}}{\sqrt{2}}$$

where V_{max} is the maximum (or peak) value of the voltage
where I_{max} is the maximum (or peak) value of the current

For sinusoidal current & voltage

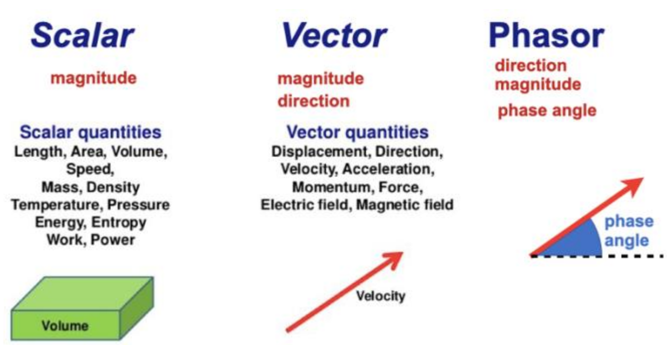
$$P_{avg} = (I_{RMS})^2 R$$

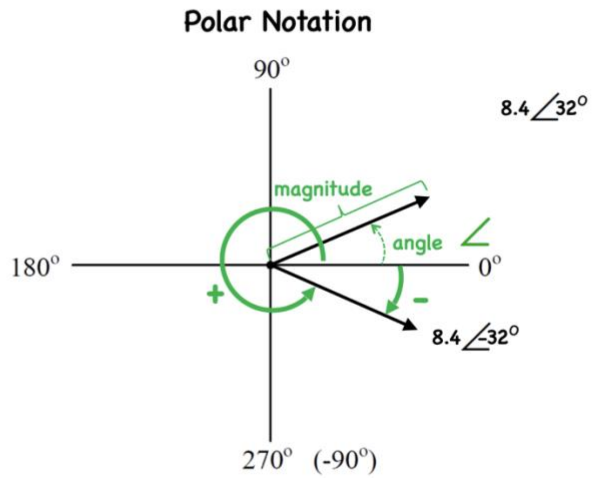
$$V_{RMS} = I_{RMS} R \qquad \text{Ohm's Law}$$

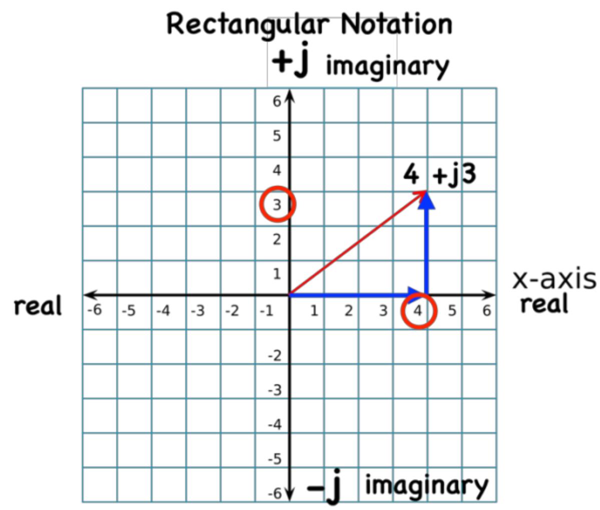
$$R = \frac{V_{RMS}}{I_{RMS}}$$

$$P_{avg} = I_{RMS} V_{RMS}$$

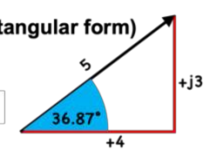
For circuits with resistive loads only







4 + j3	(rectangular form)
5 ∠ 36.87°	(polar form) → (rectangular form)
(5)(cos 36.87°) = 4	(real component)
(5)(sin 36.87°) = 3	(imaginary component)



4 + j3	(rectangular form) → (polar form)
5 ∠ 36.87°	(polar form)

$$\sqrt{4^2 + 3^2} = 5$$

$$\text{Arctan}\left(\frac{3}{4}\right) = 36.87^{o} \text{ angle}$$

Phasor Math

rectangular → polar

Multiplication $(A\angle B^\circ)(X\angle Y^\circ) = AX\angle(B^\circ+Y^\circ)$

Division $(A\angle B^\circ) \div (X\angle Y^\circ) = \frac{A}{X}\angle(B^\circ - Y^\circ)$

polar → rectangular

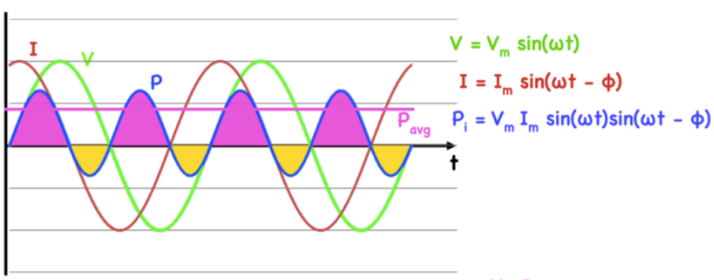
Addition $(A, B) + (X, Y) = [(A + X), (B + Y)]$

Subtraction $(A, B) - (X, Y) = [(A - X), (B - Y)]$

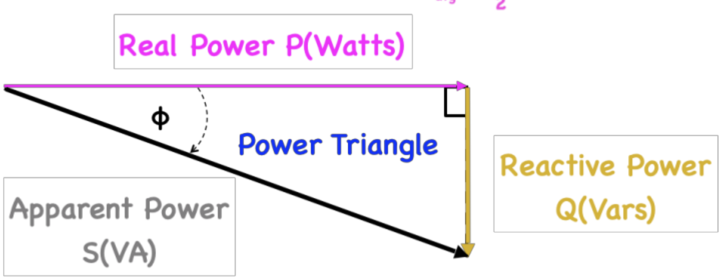
Reactancia e impedancia

Electric Power

$P_i = V_i \times I_i$



The average power is... $P_{avg} = \frac{V_M I_M}{2} \cos(\phi)$



Ø is known as the "Power Factor Angle"

cos(Ø) is known as the "Power Factor"

$$P_{avg} = \frac{V_m I_m}{2}\cos(\varnothing)$$

$$P_{avg} = \frac{V_m}{\sqrt{2}} \times \frac{I_m}{\sqrt{2}}\cos(\varnothing)$$

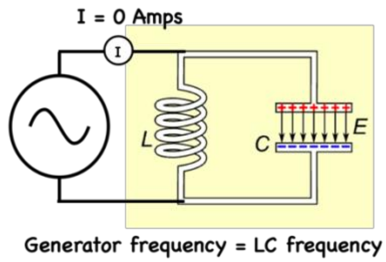
$$V_{rms} = \frac{V_m}{\sqrt{2}} \quad \text{And} \quad I_{rms} = \frac{I_m}{\sqrt{2}}$$

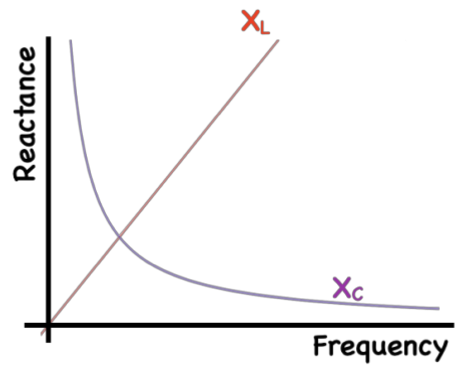
$$P_{avg} = V_{rms} \times I_{rms}\cos(\varnothing)$$

$$Q_{avg} = V_{rms} \times I_{rms}\sin(\varnothing)$$

Apparent Power (VA) = $V_{rms} \times I_{rms}$

Frecuencia armónica





$$2\pi f L = \frac{1}{2\pi f C}$$

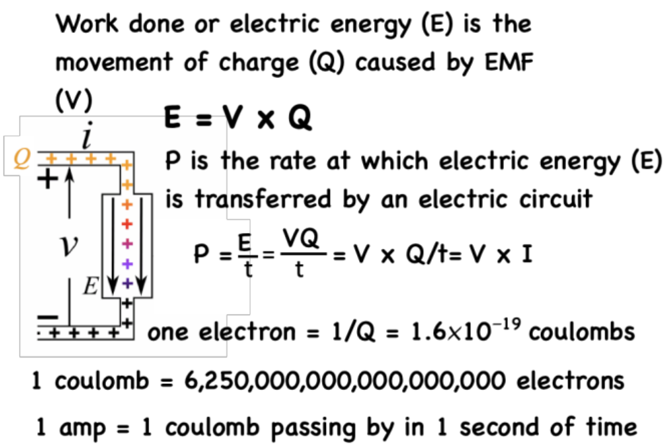
$$2\pi f^2 L = \frac{1}{2\pi C}$$

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

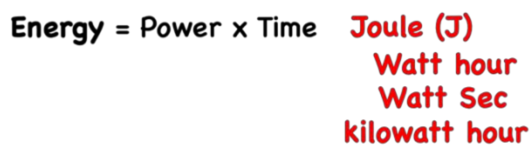
$$f = \frac{1}{2\pi\sqrt{LC}}$$

3) Análisis de potencia en circuitos de CA

Energia electrica

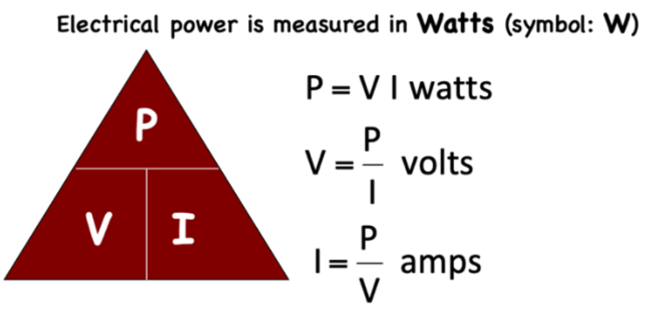


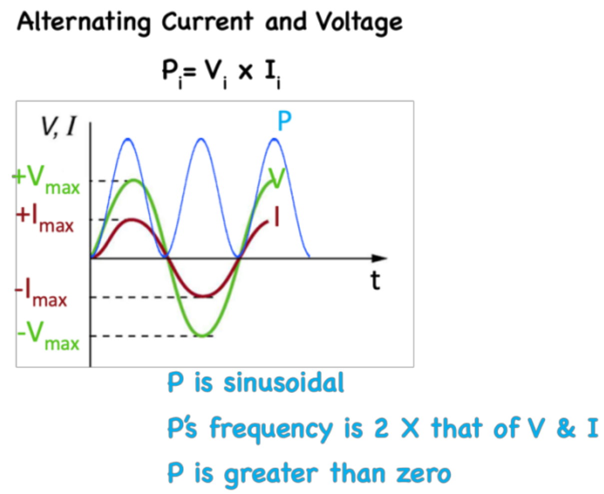
Energía eléctrica



SI multiples for watt hour (W·h)

Submultiples			Multiples		
Value	Symbol	Name	Value	Symbol	Name
10^{-3}	mW·h	milliwatt hour	10^{3}	kW·h	kilowatt hour
10^{-6}	µW·h	microwatt hour	10^{6}	MW·h	megawatt hour
			10^{9}	GW·h	gigawatt hour
			10^{12}	TW·h	terawatt hour
			10^{15}	PW·h	petawatt hour

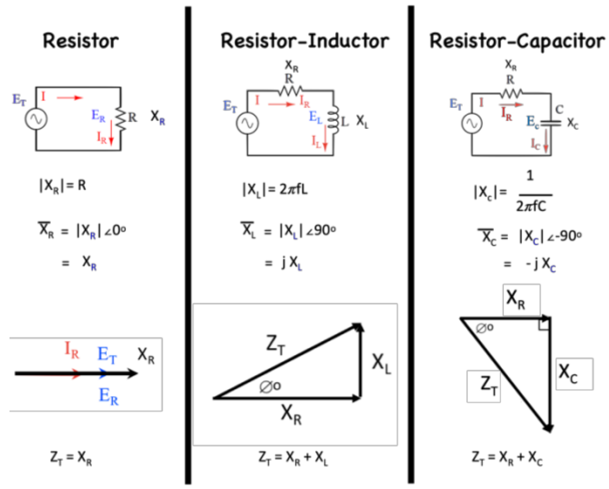




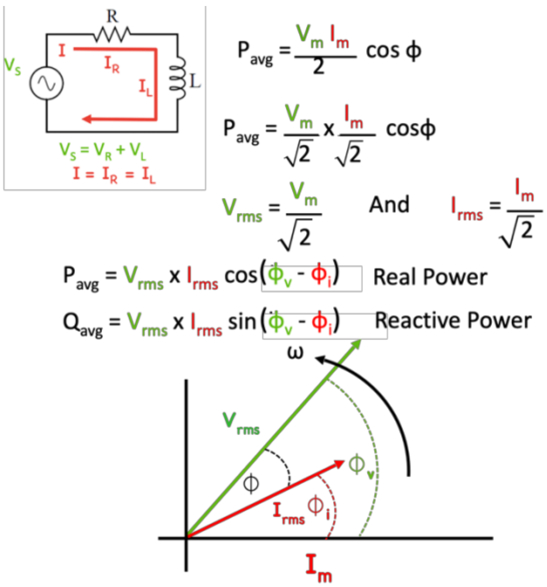
Múltiplos SI para vatios (W)

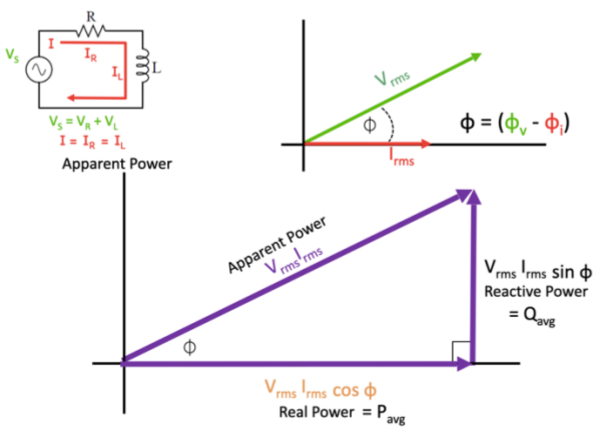
Submúltiplos			Múltiplos		
Valor	Símbolo	Nombre	Valor	Símbolo	Nombre
10^{-1}W.	dw	decivatio	10^{1}W.	grajilla	decavatio
10^{-2}W.	cw	centivatios	10^{2}W.	hw	hectovatio
10^{-3}W.	**mW**	**milivatios**	10^{3}W.	kilovatios	**kilovatio**
10^{-6}W.	**µW**	**microvatio**	10^{6}W.	megavatio	**megavatio**
10^{-9}W.	noroeste	**nanovatio**	10^{9}W.	**G.W.**	**gigavatio**
10^{-12}W.	**pW**	**picovatio**	10^{12}W.	**tw**	**teravatio**
10^{-15}W.	fW	femtovatio	10^{15}W.	VP	petavatio
10^{-18}W.	aw	attovatio	10^{18}W.	EW	exavatio
10^{-21}W.	zW	zeptovatio	10^{21}W.	ZW	zettavatio
10^{-24}W.	yW	yoctovatio	10^{24}W.	YW	yottawatt

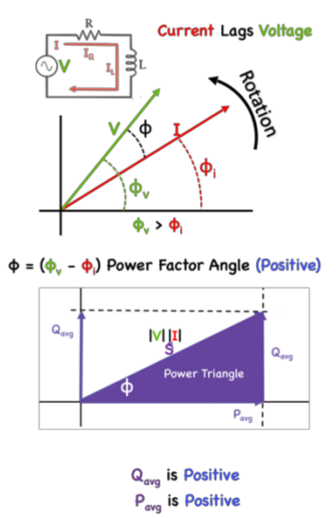
Los múltiplos comunes están en**atrevido**rostro



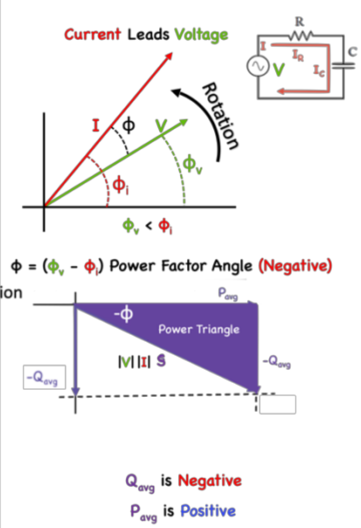
Alimentación de CA



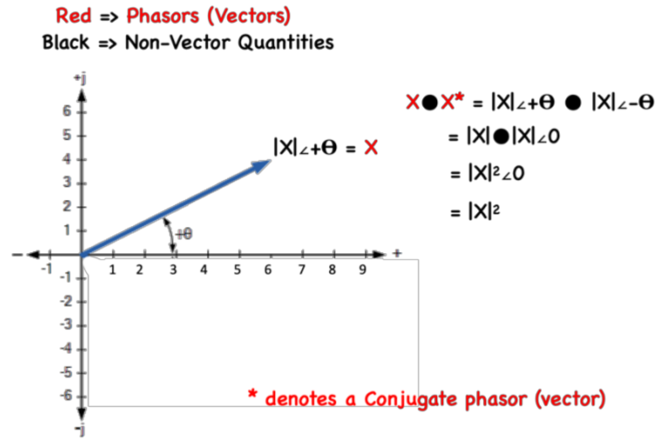


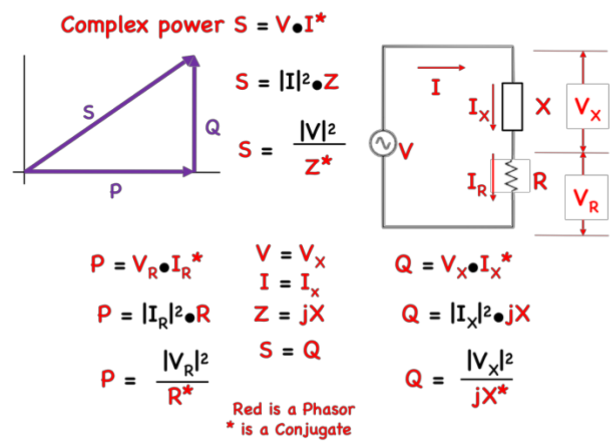


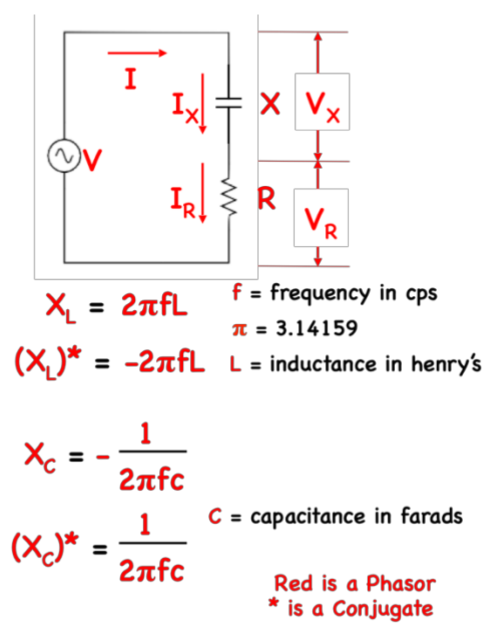
Rotation



Poder complejo



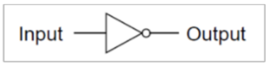




4) Circuitos eléctricos digitales

Puertas

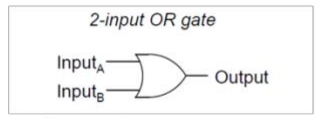
Inverter, or NOT gate



NOT gate truth table

Input	Output
0	1
1	0

The OR gate

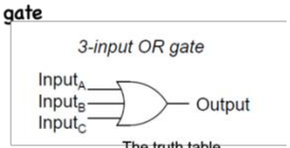


The truth table

A	B	Output
0	0	0
0	1	1
1	0	1
1	1	1

Output will be "low" (0) if and only if all inputs are "low" (0)

Output will be "high" (1) if *any* of the inputs are "high" (1)

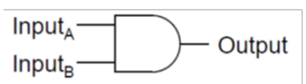


The truth table

A	B	C	Output
0	0	0	0
0	0	1	1
0	1	0	1
0	1	1	1
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	1

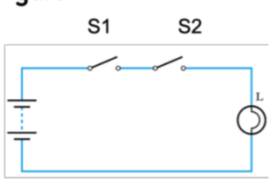
The AND gate

2-input AND gate



The truth table

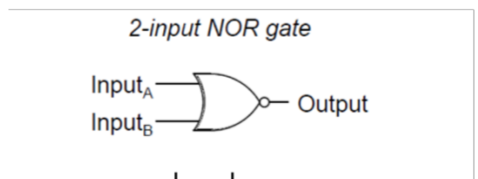
A	B	Output
0	0	0
0	1	0
1	0	0
1	1	1



The truth table

S1	S2	L
0	0	0
0	1	0
1	0	0
1	1	1

The NOR gate

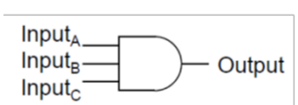


A	B	Output
0	0	1
0	1	0
1	0	0
1	1	0

Output is "high" (1) only when all inputs are "low" (0)

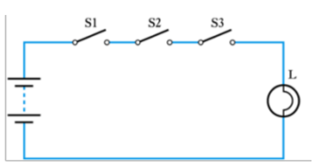
Output goes "low" (0) if any of the inputs are made "high" (1)

3-input AND gate



The truth table

A	B	C	Output
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	0
1	0	1	0
1	1	0	0
1	1	1	1

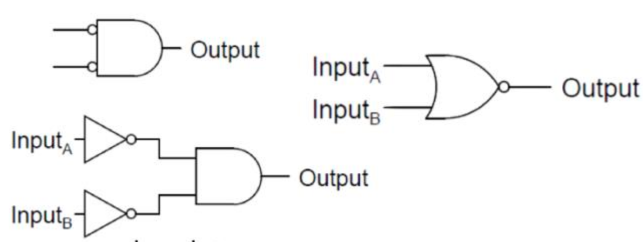


The truth table

S1	S2	S3	L
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	0
1	0	1	0
1	1	0	0
1	1	1	1

The Negative-AND gate

2-input Negative-AND gate

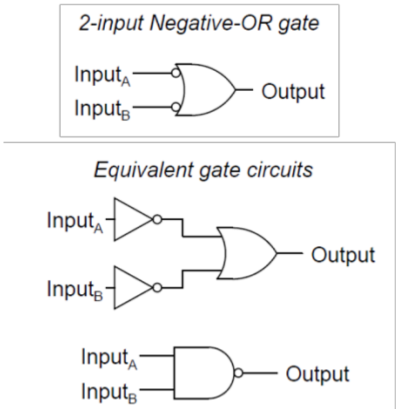


A	B	Output
0	0	1
0	1	0
1	0	0
1	1	0

Output is "high" (1) only when all inputs are "low" (0)

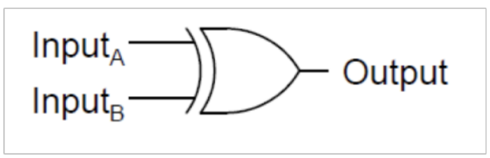
Output goes "low" (0) if any of the inputs are made "high" (1)

The Negative-OR gate



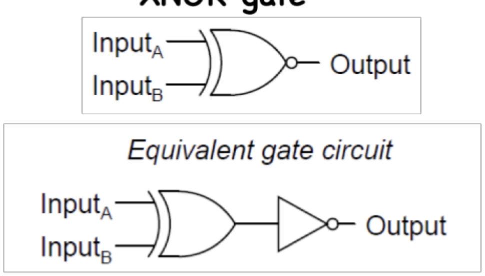
A	B	Output
0	0	1
0	1	1
1	0	1
1	1	0

The Exclusive-OR gate
(sometimes called XOR)



A	B	Output	
0	0	0	Output a "low" (0) logic level if the inputs are at the *same*
0	1	1	Output a "high" (1) logic level if the inputs are at *different*
1	0	1	
1	1	0	Output a "low" (0) logic level if the inputs are at the *same*

The Exclusive-NOR gate
XNOR gate



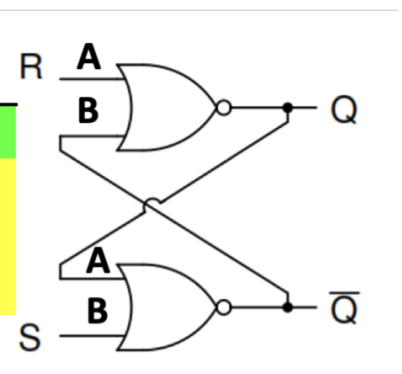
A	B	Output	
0	0	1	Output a "high" (1) logic level if the inputs are at the same
0	1	0	Output a "low" (0) logic level if the inputs are at different
1	0	0	
1	1	1	Output a "high" (1) logic level if the inputs are at the same

AND gate:
output is high only if both inputs high (A AND B are high).
OR gate:
output is high if input A OR input B are high.
NAND gate:
output is NOT high if both A input AND B input are high.
NOR gate:
output is NOT high if either A input OR B input are high.
A Negative-AND gate:
behaves like a NOR gate.
A Negative-OR gate:
behaves like a NAND gate.
Exclusive-OR gate:
output is high if the input logic levels are different.
Exclusive-NOR gate:
output is high if the input logic levels are the same.

Chanclas y multivibradores

The S-R Latch

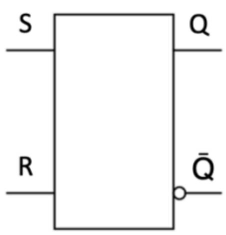
A	B	Out
0	0	1
0	1	0
1	0	0
1	1	0



S	R	Q	Q̄
0	0	latch	Latch
0	1	0	1
1	0	1	0
1	1	0	0

The S-R Latch

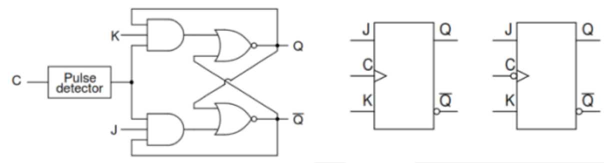
A	B	Q
0	0	1
0	1	0
1	0	0
1	1	0



S	R	Q	Q̄
0	0	latch	Latch
0	1	0	1
1	0	1	0
1	1	0	0

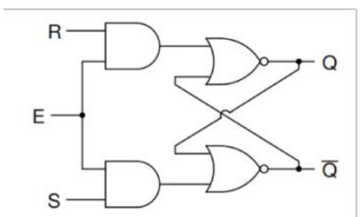
Reset
Set

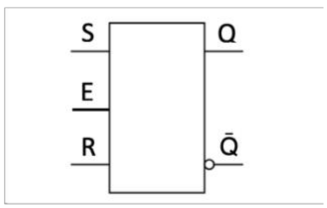
The J-K Flip-Flop



C	J	K	Q	Q̄
⌈	0	0	Latch	Latch
⌈	0	1	0	1
⌈	1	0	1	0
⌈	1	1	Toggle	Toggle
X	0	0	Latch	Latch
X	0	1	Latch	Latch
X	1	0	Latch	Latch
X	1	1	Latch	Latch

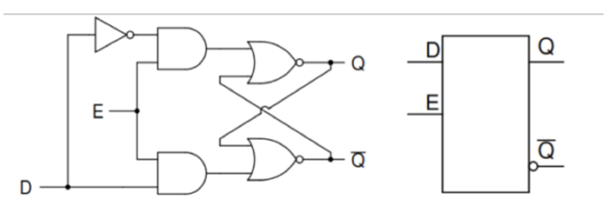
The Gated S-R Latch





E	S	R	Q	Q̄
0	0	0	Latch	Latch
0	0	1	Latch	Latch
0	1	0	Latch	Latch
0	1	1	Latch	Latch
1	0	0	Latch	Latch
1	0	1	0	1
1	1	0	1	0
1	1	1	0	0

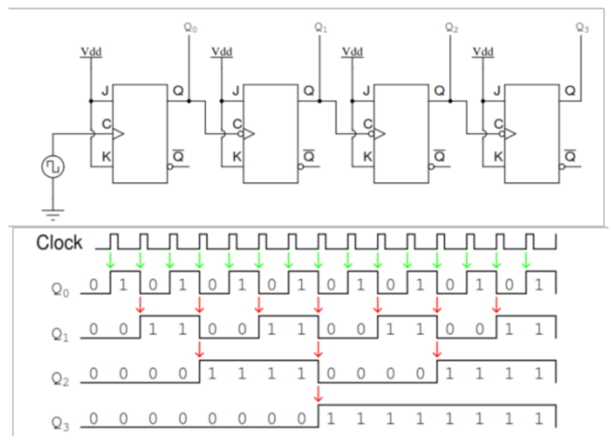
The D Latch



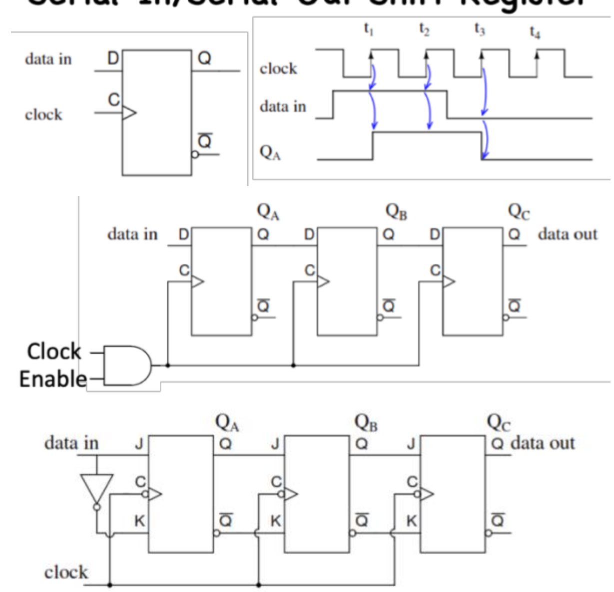
E	D	Q	Q̄
0	0	Latch	Latch
0	1	Latch	Latch
1	0	0	1
1	1	1	0

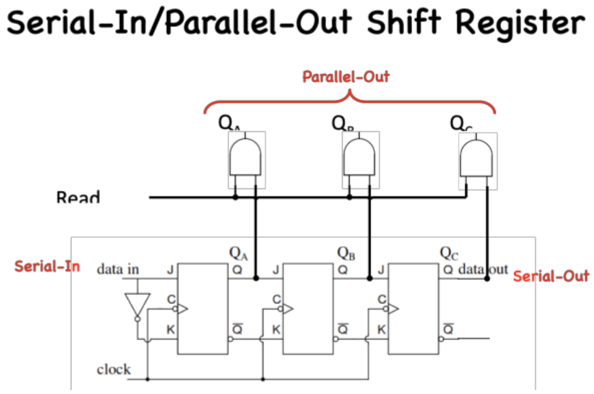
Contadores y registros de turnos

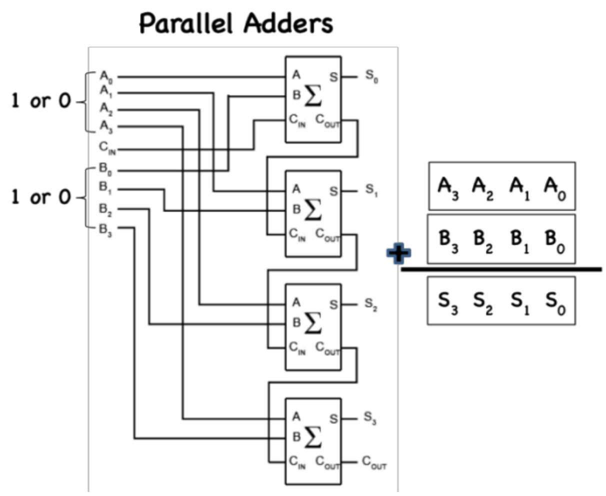
A Four-Bit "Up" Counter



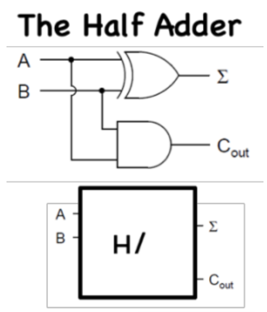
Serial-In/Serial-Out Shift Register





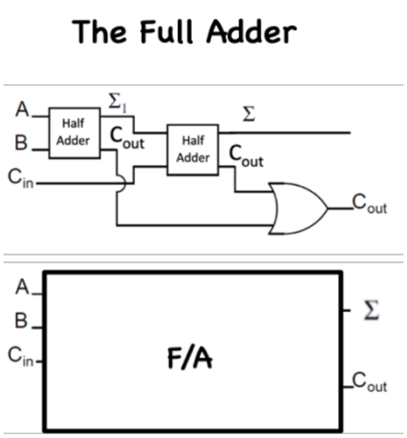


sumadores



A	B	Σ	C_{out}
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

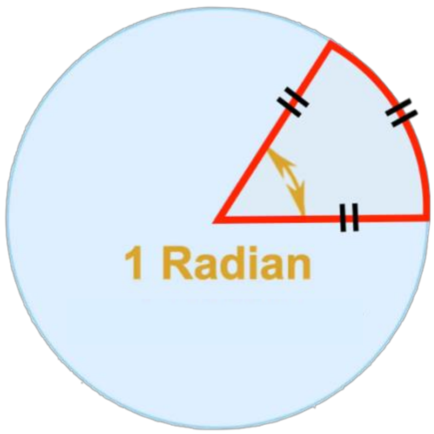
0 plus 0 = 0
0 plus 1 = 1
1 plus 0 = 1
1 plus 1 = 0 Carry 1

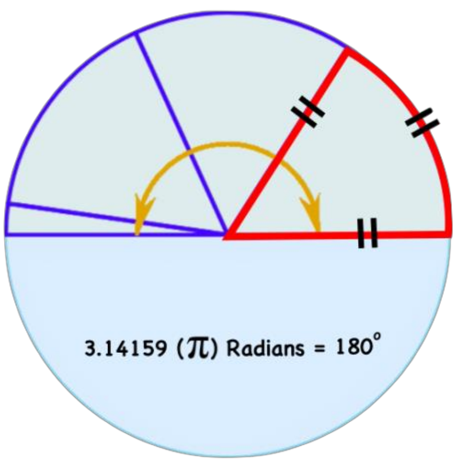


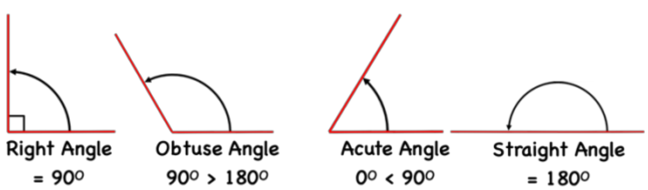
A	B	Carry-In	Sum	Carry-Out
0	0	0	0	0
0	0	1	1	0
0	1	0	1	0
0	1	1	0	1
1	0	0	1	0
1	0	1	0	1
1	1	0	0	1
1	1	1	1	1

5) Trigonometría eléctrica

Medición de ángulo







Congruent Angles - equal ≅

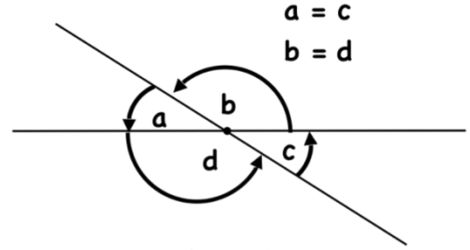
Supplemental angles-add to 180º

Complementary angles -add to 90º

Opposite Angles of Intersecting Lines Are Equal

a = c

b = d



a + b = 180º

c + b = 180º

a + ~~b~~ = c + ~~b~~

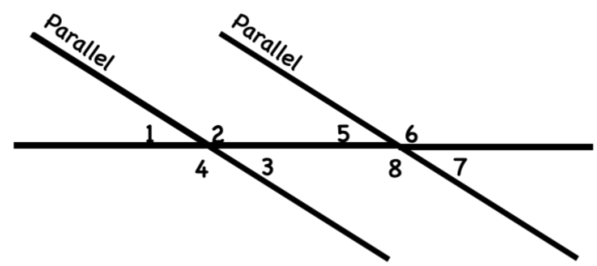
a = c

a + d = 180º

a + b = 180º

~~a~~ + d = ~~a~~ + b

b = d



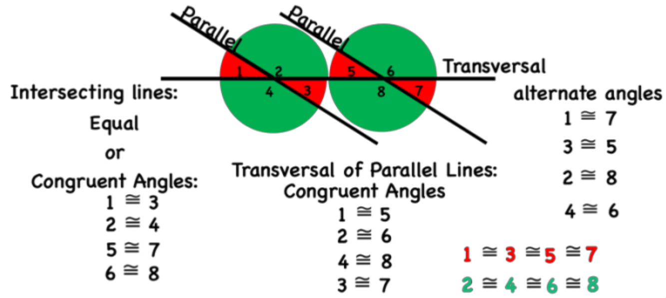
Transversal-same side exterior angles 1; 6; 4; 7
-same side interior angles 2; 3; 8; 5

Corresponding Angles

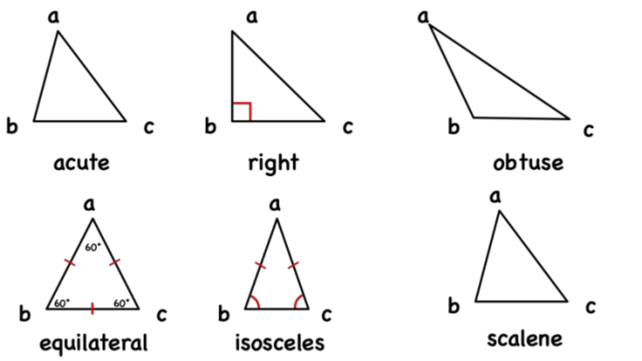
same side of Transversal 1 & 5

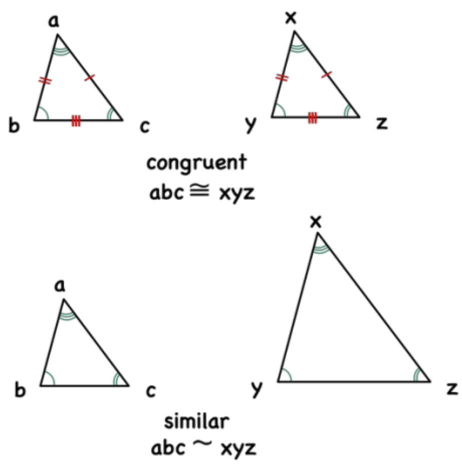
and

same position w.r.t. parallel lines 2 & 6
4 & 8
3 & 7

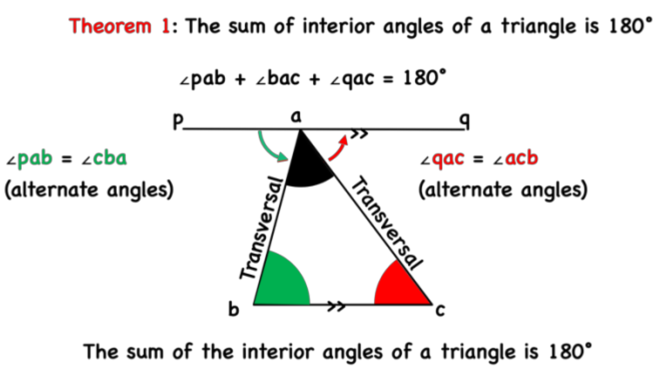


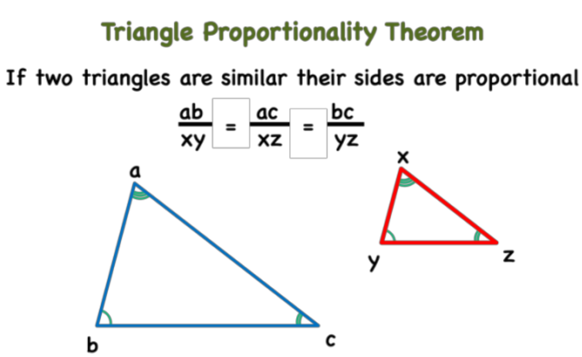
triangulos

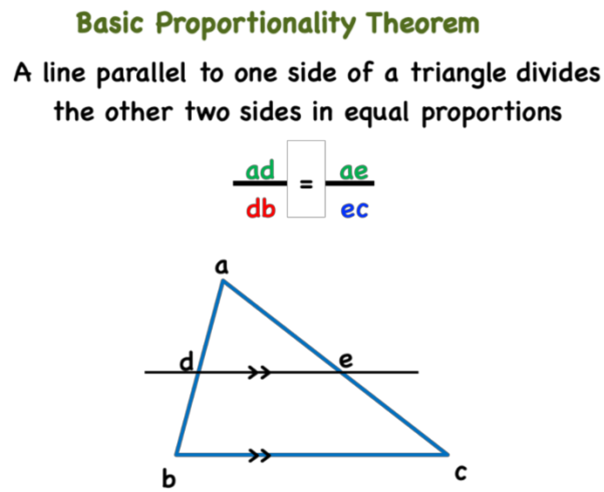


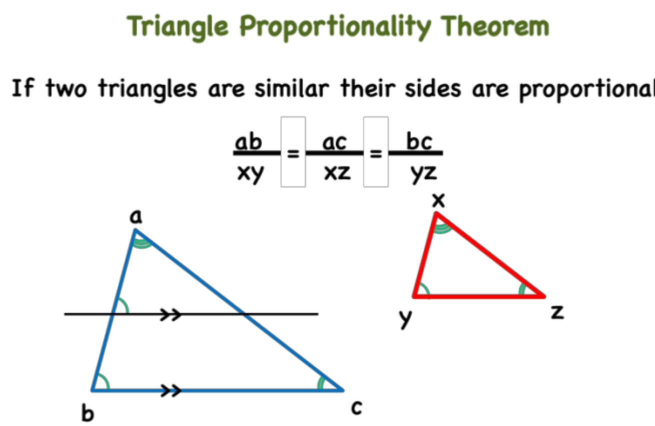


Propiedad de la suma de ángulos de un triángulo

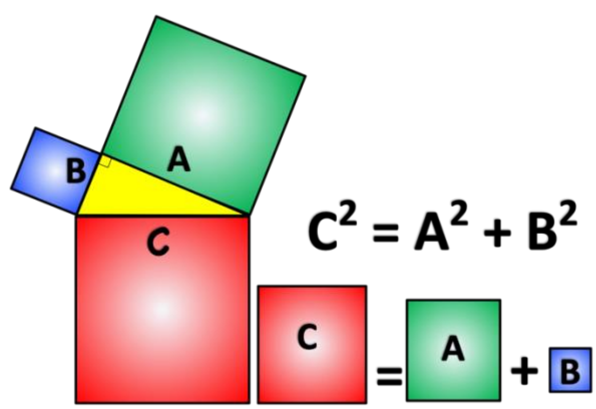




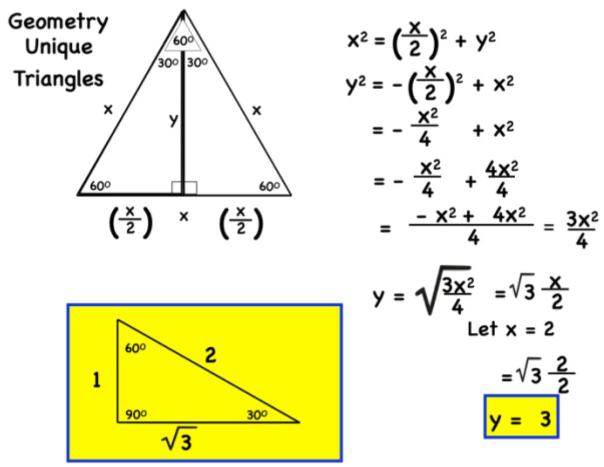


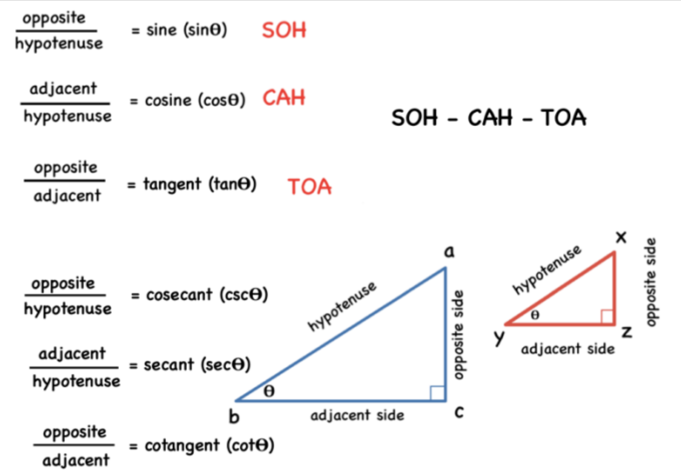


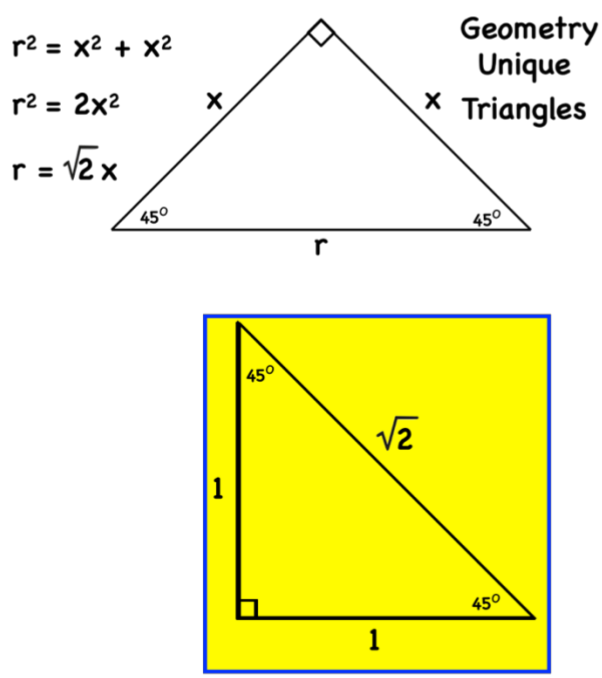
El teorema de Pitágoras

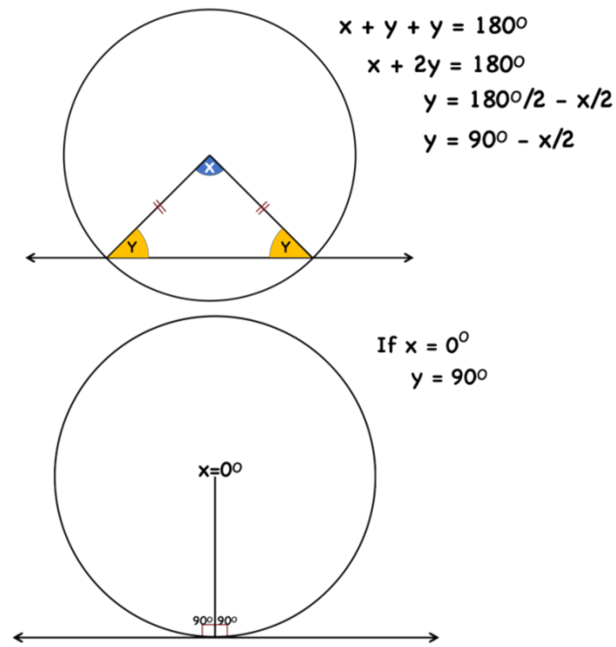


Triángulos y proporciones únicos



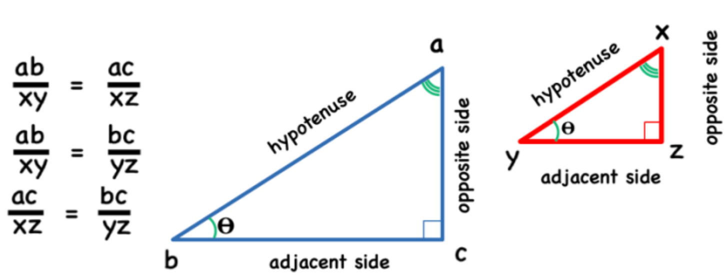






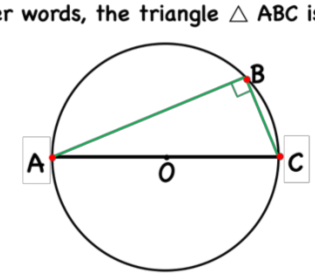
The radius line of a circle meets the tangent line at 90°

Funciones trigonométricas y tangente

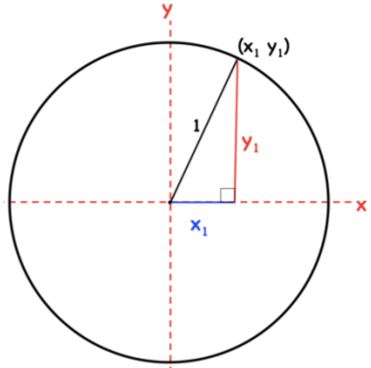


Thale's Theorem

If A, B, and C are (distinct) points on a circle such that the line segment AC is a diameter of the circle, then the angle ∠ ABC is a right angle. In other words, the triangle △ ABC is a right triangle.

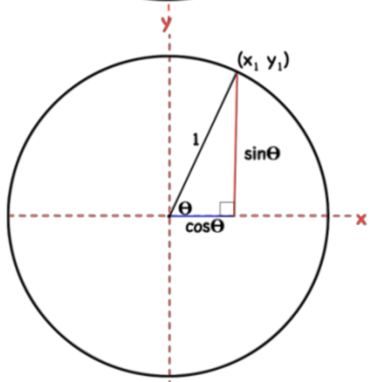


El círculo unitario



$$\sin\Theta = \frac{\text{opposite side}}{\text{hypotenuse}} = \frac{y_1}{1}$$

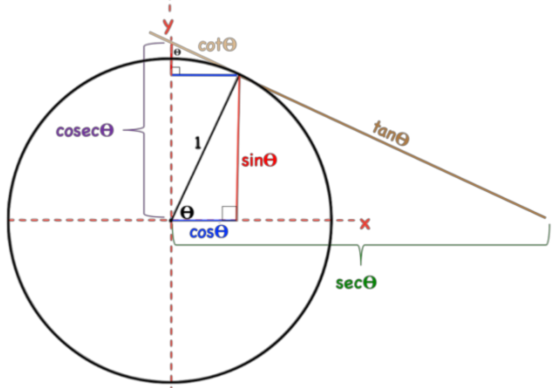
$$\sin\Theta = y_1$$

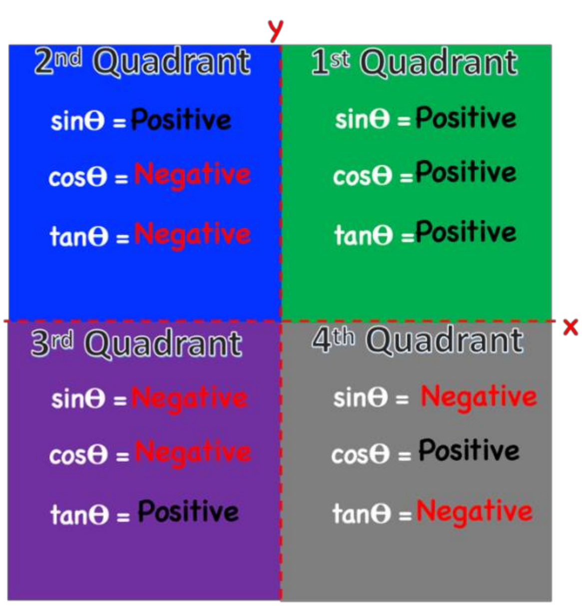


$$\cos\Theta = \frac{\text{adjacent side}}{\text{hypotenuse}} = \frac{x_1}{1}$$

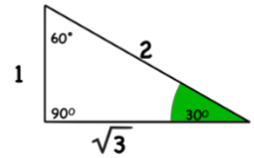
$$\cos\Theta = x_1$$

$$\tan\Theta = \frac{\text{opposite side}}{\text{adjacent side}}$$





Triángulos únicos



sine (sin) $30° = \frac{1}{2}$ $\frac{\text{opposite}}{\text{hypotenuse}}$

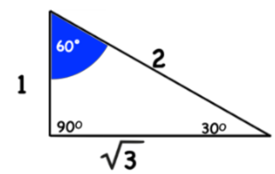
cosine (cos) $30° = \frac{\sqrt{3}}{2}$ $\frac{\text{adjacent}}{\text{hypotenuse}}$

tangent (tan) $30° = \frac{1}{\sqrt{3}}$ $\frac{\text{opposite}}{\text{adjacent}}$

cosecant (csc) $30° = \frac{2}{1}$ reciprocal of sin θ

secant (sec) $30° = \frac{2}{\sqrt{3}}$ reciprocal of cos θ

cotangent (cot) $30° = \frac{\sqrt{3}}{1}$ reciprocal of tan θ



sine (sin) $60° = \frac{\sqrt{3}}{2}$ $\frac{\text{opposite}}{\text{hypotenuse}}$

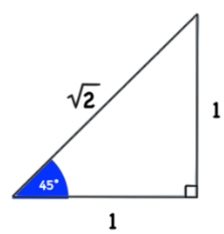
cosine (cos) $60° = \frac{1}{2}$ $\frac{\text{adjacent}}{\text{hypotenuse}}$

tangent (tan) $60° = \frac{\sqrt{3}}{1}$ $\frac{\text{opposite}}{\text{adjacent}}$

cosecant (csc) $60° = \frac{2}{\sqrt{3}}$ reciprocal of sin θ

secant (sec) $60° = \frac{2}{1}$ reciprocal of cos θ

cotangent (cot) $60° = \frac{1}{\sqrt{3}}$ reciprocal of Tan θ



sine (sin) $45° = \frac{1}{\sqrt{2}}$ $\frac{\text{opposite}}{\text{hypotenuse}}$

cosine (cos) $45° = \frac{1}{\sqrt{2}}$ $\frac{\text{adjacent}}{\text{hypotenuse}}$

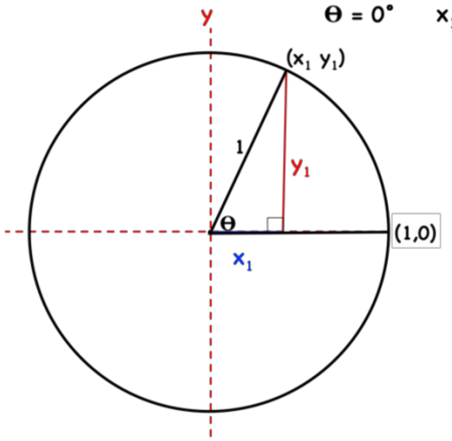
tangent (tan) $45° = \frac{1}{1}$ $\frac{\text{opposite}}{\text{adjacent}}$

cosecant (csc) $45° = \frac{\sqrt{2}}{1}$ reciprocal of sin θ

secant (sec) $45° = \frac{\sqrt{2}}{1}$ reciprocal of cos θ

cotangent (cot) $45° = \frac{1}{1}$ reciprocal of Tan θ

Ángulos únicos

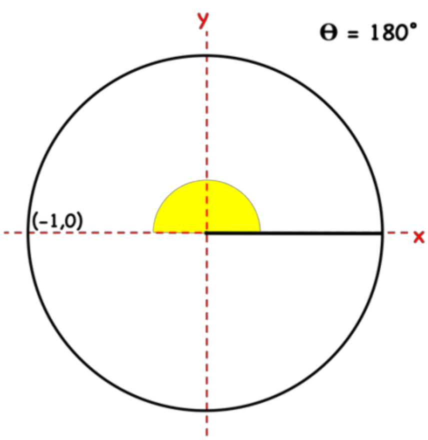


$\Theta = 0°$ $\quad x_1 = 1$ $\quad y_1 = 0$

$\sin\Theta = \frac{y_1}{1} = \frac{0}{1} = 0$

$\cos\Theta = \frac{x_1}{1} = \frac{1}{1} = 1$

$\tan\Theta = \frac{y_1}{x_1} = \frac{0}{1} = 0$

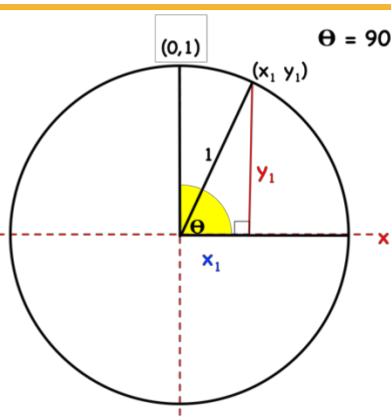


$\Theta = 180°$ $\quad x_1 = -1$ $\quad y_1 = 0$

$\sin\Theta = \frac{y_1}{1} = \frac{0}{1} = 0$

$\cos\Theta = \frac{x_1}{1} = \frac{-1}{1} = -1$

$\tan\Theta = \frac{y_1}{x_1} = \frac{0}{-1} = 0$

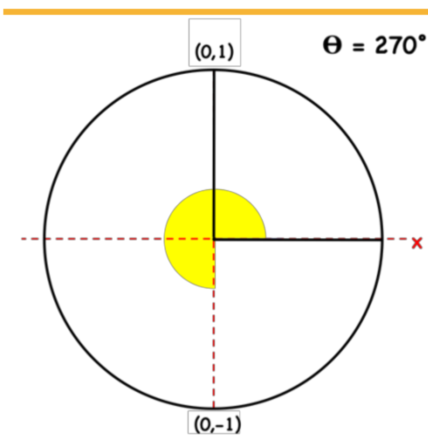


$\Theta = 90°$ $\quad x_1 = 0$ $\quad y_1 = 1$

$\sin\Theta = \frac{y_1}{1} = \frac{1}{1} = 1$

$\cos\Theta = \frac{x_1}{1} = \frac{0}{1} = 0$

$\tan\Theta = \frac{y_1}{x_1} = \frac{1}{0} = \infty$



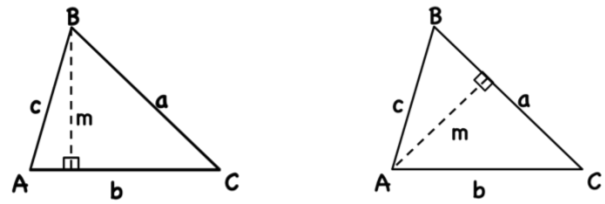
$\Theta = 270°$ $\quad x_1 = 0$ $\quad y_1 = -1$

$\sin\Theta = \frac{y_1}{1} = \frac{-1}{1} = -1$

$\cos\Theta = \frac{x_1}{1} = \frac{0}{1} = 0$

$\tan\Theta = \frac{y_1}{x_1} = \frac{-1}{0} = -\infty$

La ley de los senos



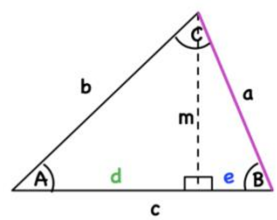
$\sin A = \frac{m}{c}$ $\quad \sin C = \frac{m}{a}$ $\quad \sin B = \frac{m}{c}$ $\quad \sin C = \frac{m}{b}$

$c \sin A = m$ $\quad a \sin C = m$ $\quad c \sin B = m$ $\quad b \sin C = m$

$c \sin A = a \sin C$ $\quad c \sin B = b \sin C$

$\frac{\sin A}{a} = \frac{\sin C}{c}$ $\quad \frac{\sin B}{b} = \frac{\sin C}{c}$

La ley de los cosenos



$\cos(A) = \frac{d}{b}$ $\quad d = b\cos(A)$

$e = c - d$

$e = c - b\cos(A)$

$\sin(A) = \frac{m}{b}$ $\quad m = b\sin(A)$

$a^2 = m^2 + e^2$

$a^2 = (b\sin(A))^2 + (c - b\cos(A))^2$

$a^2 = b^2\sin^2(A) + c^2 - 2bc\cos(A) + b^2\cos^2(A)$

$= b^2(\sin^2(A) + \cos^2(A)) + c^2 - 2bc\cos(A)$ (1)

$a^2 = b^2 + c^2 - 2bc\cos(A)$

$b^2 = a^2 + c^2 - 2ac\cos(B)$

$c^2 = a^2 + b^2 - 2ab\cos(C)$

Given Two Sides
&
the
Contained Angle
Third Side
Can be
Calculated

Identidades trigonométricas

Reciprocal Identities

$\csc\theta = 1/(\sin\theta)$

$\sec\theta = 1/(\cos\theta)$

$\cot\theta = 1/(\tan\theta)$

$\sin\theta = 1/(\csc\theta)$

$\cos\theta = 1/(\sec\theta)$

$\tan\theta = 1/(\cot\theta)$

Negative Angle Identities

$\sin(-\theta) = -\sin\theta$

$\cos(-\theta) = \cos\theta$

$\tan(-\theta) = -\tan\theta$

$\csc(-\theta) = -\csc\theta$

$\sec(-\theta) = \sec\theta$

$\cot(-\theta) = -\cot\theta$

Quotient Identities

$\tan\theta = (\sin\theta)/(\cos\theta)$

$\cot\theta = (\cos\theta)/(\sin\theta)$

Pythagorean Identities

$\sin^2\theta + \cos^2\theta = 1$

$1 - \cos^2 x = \sin^2 x$

$1 - \sin^2 x = \cos^2 x$

Sum & Difference Formulas

$\sin(\alpha + \beta) = \sin\alpha\cos\beta + \cos\alpha\sin\beta$

$\sin(\alpha - \beta) = \sin\alpha\cos\beta - \cos\alpha\sin\beta$

$\cos(\alpha + \beta) = \cos\alpha\cos\beta - \sin\alpha\sin\beta$

$\cos(\alpha - \beta) = \cos\alpha\cos\beta + \sin\alpha\sin\beta$

Trig Identity for: $\sin(x - y) = \sin x \cdot \cos y - \cos x \cdot \sin y$

$\sin(x + y) = \sin x \cdot \cos y + \cos x \cdot \sin y$

$\sin(x + (-y)) = \sin x \cdot \cos(-y) + \cos x \cdot \sin(-y)$

$\sin(x - y) = \sin x \cdot \cos y - \cos x \cdot \sin y$

Trig Identity for: $\cos(x - y) = \cos x \cdot \cos y + \sin x \cdot \sin y$

$\cos(x + y) = \cos x \cdot \cos y - \sin x \cdot \sin y$

$\cos(x + (-y)) = \cos x \cdot \cos(-y) - \sin x \cdot \sin(-y)$

$\cos(x - y) = \cos x \cdot \cos y + \sin x \cdot \sin y$

$\cos(y) = \cos(-y)$

$\sin(-y) = -\sin(y)$

Fórmulas de producto a suma

$$\sin x \cdot \sin y = (1/2)[\cos(x - y) - \cos(x + y)]$$

$$\cos x \cdot \cos y = (1/2)[\cos(x + y) + \cos(x - y)]$$

$$\sin x \cdot \cos y = (1/2)[\sin(x + y) + \sin(x - y)]$$

$$\cos x \cdot \sin y = (1/2)[\sin(x + y) - \sin(x - y)]$$

Fórmulas de suma a producto

$$\sin x + \sin y = 2 \sin\left(\frac{x+y}{2}\right)\cos\left(\frac{x-y}{2}\right)$$

$$\sin x - \sin y = 2 \cos\left(\frac{x+y}{2}\right)\sin\left(\frac{x-y}{2}\right)$$

$$\cos x + \cos y = 2 \cos\left(\frac{x+y}{2}\right)\cos\left(\frac{x-y}{2}\right)$$

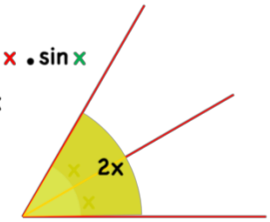
$$\cos x - \cos y = -2 \sin\left(\frac{x+y}{2}\right)\sin\left(\frac{x-y}{2}\right)$$

Fórmulas de doble ángulo

$$\sin 2x = \sin(x + x) = \sin x \cdot \cos x + \cos x \cdot \sin x$$

$$= \sin x \cdot \cos x + \cos x \cdot \sin x$$

$$= 2\sin x \cdot \cos x$$



$$\cos 2x = \cos(x + x) = \cos x \cdot \cos x - \sin x \cdot \sin x$$

$$= \cos^2 x - \sin^2 x$$

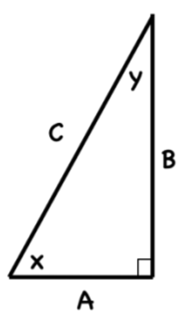
$$= 2\cos^2 x - 1$$

$$= 1 - 2\sin^2 x$$

$$\tan 2x = \frac{\sin 2x}{\cos 2x} = \frac{\sin x \cdot \cos x + \cos x \cdot \sin x}{\cos^2 x - \sin^2 x} \cdot \frac{\cos^2 x}{\cos^2 x}$$

$$= \frac{\dfrac{\sin x \cdot \cos x}{\cos^2 x} + \dfrac{\cos x \cdot \sin x}{\cos^2 x}}{\dfrac{\cos^2 x - \sin^2 x}{\cos^2 x}} = \frac{2\tan x}{1 - \tan^2 x}$$

Identidades de cofunción



$$y = 90° - x$$

$$\cos y = \frac{B}{C} = \sin x \qquad \sec y = \frac{C}{B} = \csc x$$

$$\cos(90° - x) = \sin x \qquad \sec(90° - x) = \csc x$$

$$\sin y = \frac{A}{C} = \cos x \qquad \csc y = \frac{C}{A} = \sec x$$

$$\sin(90° - x) = \cos x \qquad \csc(90° - x) = \sec x$$

$$\tan y = \frac{A}{B} = \cot x \qquad \cot y = \frac{B}{A} = \tan x$$

$$\tan(90° - x) = \cot x \qquad \cot(90° - x) = \tan x$$

06) Derivados

Propiedades límite

$$\lim_{x\to c} f(x) = L \qquad \lim_{x\to c} g(x) = M$$

$\lim_{x\to c} \left(f(x) + g(x)\right) = \lim_{x\to c} f(x) + \lim_{x\to c} g(x) = L + M$ — The "Sum" Property

$\lim_{x\to c} \left(f(x) - g(x)\right) = L - M$ — The "Difference" Property

$\lim_{x\to c} \left(f(x)\, g(x)\right) = \lim_{x\to c} f(x) \lim_{x\to c} g(x) = L\, M$ — The "Multiple" Property

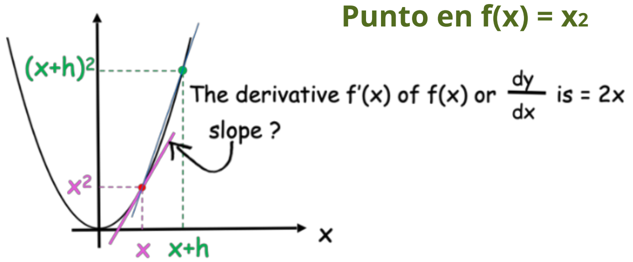
$\lim_{x\to c} k f(x) = k \lim_{x\to c} f(x) = kL$ — The "Constant Multiple" Property

$\lim_{x\to c} \frac{f(x)}{g(x)} = \frac{\lim_{x\to c} f(x)}{\lim_{x\to c} g(x)} = \frac{L}{M}$ — The "Quotient" Property

$\lim_{x\to c} \left(f(x)\right)^{R/S} = \left(\lim_{x\to c} f(x)\right)^{R/S} = L^{R/S}$ — The "Exponent" Property

La pendiente de la tangente

Punto en $f(x) = x^2$



Derivados comunes

Polynomials (c = constant x = variable)

$$\frac{d}{dx}(c) = 0 \qquad \frac{d}{dx}(x) = 1$$

$$\frac{d}{dx}(cx) = c \qquad \frac{d}{dx}(x^n) = nx^{n-1} \qquad \frac{d}{dx}(cx^n) = ncx^{n-1}$$

Derivados comunes (continuación)

Trig Functions

$$\frac{d}{dx}(\sin x) = \cos x \qquad \frac{d}{dx}(\cos x) = -\sin x$$

$$\frac{d}{dx}(\tan x) = \sec^2 x \qquad \frac{d}{dx}(\cot x) = -\csc^2 x$$

$$\frac{d}{dx}(\sec x) = \sec x \tan x \qquad \frac{d}{dx}(\csc x) = -\csc x \cot x$$

Exponential/Logarithm Functions

$$\frac{d}{dx}(a^x) = a^x \ln(a) \qquad \frac{d}{dx}(e^x) = e^x$$

$$\frac{d}{dx}(\ln x) = \frac{1}{x} \quad x > 0 \qquad \frac{d}{dx}(\ln |x|) = \frac{1}{x} \quad x \neq 0$$

$$\frac{d}{dx}(\log_a x) = \frac{1}{x\ln(a)} \quad x > 0$$

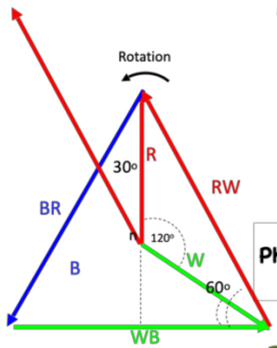
El teorema de la compresión

$$\lim_{x\to 0} \frac{1 - \cos x}{x} = 0$$

$$\lim_{\theta\to 0} \frac{\sin\theta}{\theta} = 1$$

7) Análisis por unidad

Relaciones de fase



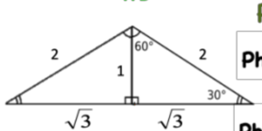
Magnitude:

$$\frac{W}{WB} = \frac{2}{2\sqrt{3}} = \frac{R}{RW} = \frac{B}{BR}$$

Phase to Phase = $\sqrt{3}$ Phase to Neutral

$$\text{Phase to Neutral} = \frac{\text{Phase to Phase}}{\sqrt{3}}$$

Phase Angle:

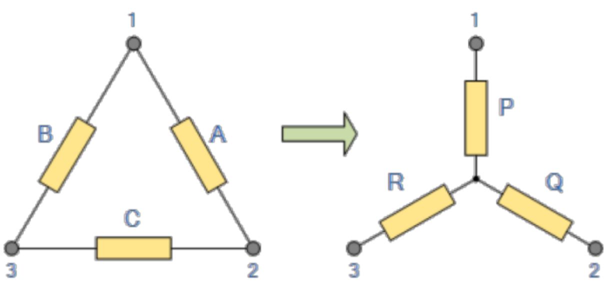


Phase to Neutral **Lags** Phase to Phase by 30º

or

Phase to Phase **Leads** Phase to Neutral by 30º

Conversiones Δ - Y



$$P = \frac{AB}{A + B + C} \qquad Q = \frac{AC}{A + B + C} \qquad R = \frac{BC}{A + B + C}$$

Normalización

1) Specify the **VA or S Base**

2) Determine the **Voltage Base**

3) Determine **Impedance Bases and Current Bases** from VA Base & each Voltage Bases

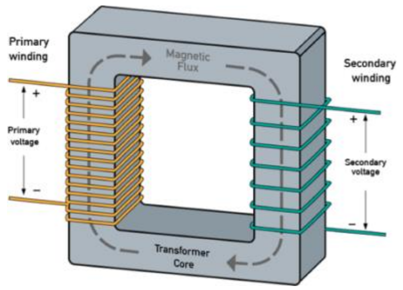
4) **Per unit** quantities are calculated by dividing the actual value by its equivalent base value

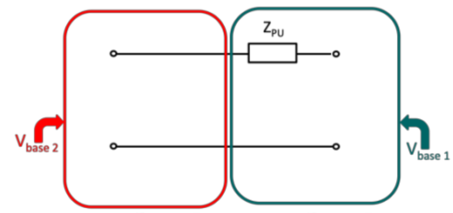
5) For each component, it's actual value may be found by multiplying its **per unit** quantity by the base value for that quantity at its connected location

$$\text{Quantity in PU} = \frac{\text{Actual value of Quantity}}{\text{Base value of Quantity}}$$

$$\text{Actual value of Quantity} = \text{Quantity in PU} \times \text{Base value of Quantity}$$

Transformadores y análisis por unidad





$Z_{Actual} = Z_{base} \times Z_{PU}$ $\qquad$ $Z_{Actual} = Z_{base} \times Z_{PU}$

$Z_{Base} = \frac{kV^2}{MVA_{Base}}$ $\qquad$ $Z_{Base} = \frac{kV^2}{MVA_{Base}}$

$$Z_{H\ pu} = Z_{L\ pu}$$

1) Specify the **VA Base** **Base Values are Magnitude Only |Quantity| VA**

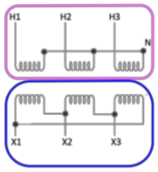
$$S^{3\Phi}_{base} = 3S^{1\Phi}_{base} = P^{3\Phi}_{base} = Q^{3\Phi}_{base} = 3P^{1\Phi}_{base} = 3Q^{1\Phi}_{base}$$

Base values of real power, reactive power, and complex power have the same base value number

2) Determine or pick a **Voltage Base** **|Quantity|** **Volts** $\quad V^{LN}_{base} = \frac{V^{LL}_{base}}{\sqrt{3}}$

There is a voltage base for each and every voltage level in the system

Transformer voltage ratios are given as **line-to-line** voltage



230 kV/115 kV
Y-△

3) Determine **Impedance Bases and Current Bases** from VA Base & each Voltage Bases

Current Bases:

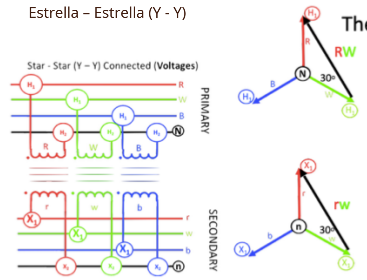
$$I_{base} = \frac{S^{1\Phi}_{base}}{V^{LN}_{base}} = \frac{\frac{S^{3\Phi}_{base}}{3}}{\frac{V^{LL}_{base}}{\sqrt{3}}} = \frac{\sqrt{3}\,S^{3\Phi}_{base}}{3\ V^{LL}_{base}} = \frac{\sqrt{3}\,S^{3\Phi}_{base}}{\sqrt{3}\sqrt{3}\ V^{LL}_{base}} = \frac{S^{3\Phi}_{base}}{\sqrt{3}\ V^{LL}_{base}}$$

Impedance Bases:

$$Z_{base} = \frac{V^{LN}_{base}}{I_{base}} = \frac{(V^{LN}_{base})^2}{S^{1\Phi}_{base}} = \frac{\left(\frac{V^{LL}_{base}}{\sqrt{3}}\right)^2}{\frac{S^{3\Phi}_{base}}{3}} = \frac{1/3\,(V^{LL}_{base})^2}{1/3\ S^{3\Phi}_{base}} = \frac{(V^{LL}_{base})^2}{S^{3\Phi}_{base}}$$

Conexiones del transformador

Estrella – Estrella (Y - Y)



The Primary Voltage Relationship:

$$RW = \sqrt{3}\, RN \angle 30^\circ$$

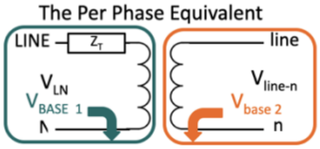
$$V_{LL} = \sqrt{3}\, V_{LN} \angle 30^\circ$$

The Secondary Voltage Relationship:

$$rw = \sqrt{3}\, rn \angle 30^\circ$$

$$V_{line\text{-}line} = \sqrt{3}\, V_{line\text{-}n} \angle 30^\circ$$

The Per Phase Equivalent

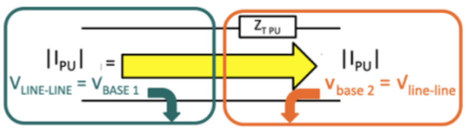


The Turns Ratio of the Transformer:

$$\frac{V_{LN}}{V_{line\text{-}n}} = a = \frac{R}{r} = \frac{W}{w} = \frac{B}{b}$$

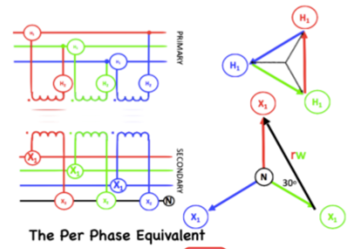
$$\frac{V_{LL}}{V_{line\text{-}line}} = a = \frac{I_{line}}{Prim\ I_{LINE}}$$

The Per Unit Equivalent



$$Z_{H\,pu} = Z_{L\,pu}$$

Delta - Star (△- Y)



The Secondary Voltage Relationship:

$$rw = \sqrt{3}\, rn \angle 30^\circ \qquad V_{line\text{-}n} = \frac{V_{line\text{-}line}}{\sqrt{3}\angle 30^\circ}$$

$$V_{line\text{-}line} = \sqrt{3}\, V_{line\text{-}n} \angle 30^\circ$$

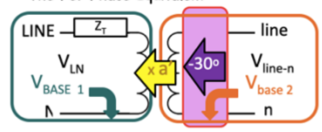
The Per Phase Turns Ratio $\quad \dfrac{V_{LL}}{V_{line\text{-}n}} = a$

$$V_{line\text{-}n} = \frac{V_{LL}}{a}$$

$$V_{LN} = \frac{V_{LL}}{\sqrt{3}\angle 30^\circ}$$

$$V_{LL} = \sqrt{3}\, V_{LN} \angle 30^\circ$$

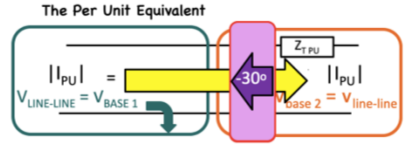
The Per Phase Equivalent



$$V_{LN} = \frac{V_{LL} \angle -30^\circ}{\sqrt{3}}$$

$$\frac{V_{LN}}{V_{line\text{-}n}} = \frac{a\ V_{LL} \angle -30^\circ}{\sqrt{3}\ V_{LL}} \qquad a' = \frac{a}{\sqrt{3}}$$

The Per Unit Equivalent

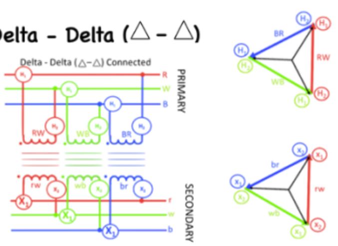


$$V_{LN} = a'\, V_{line\text{-}n} \angle -30^\circ$$

$$V_{LL} = a'\, V_{line\text{-}line} \angle -30^\circ$$

$$I_{Line\,prim} = \frac{1}{a'}\, I_{line\text{-}sec} \angle -30^\circ$$

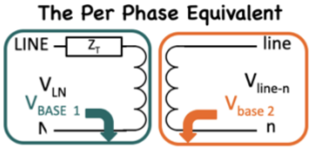
Delta - Delta (△ - △)



The Turns Ratio of the Transformer:

$$\frac{V_{LL}}{V_{line\text{-}line}} = a = \frac{RW}{rw} = \frac{WB}{wb} = \frac{BR}{br}$$

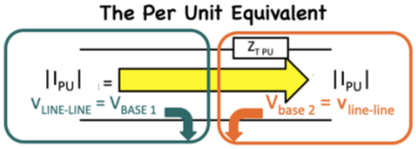
The Per Phase Equivalent



$$V_{LN} = \frac{V_{LL}}{\sqrt{3}} \angle -30^\circ$$

$$V_{line\text{-}n} = \frac{V_{line\text{-}line}}{\sqrt{3}} \angle -30^\circ$$

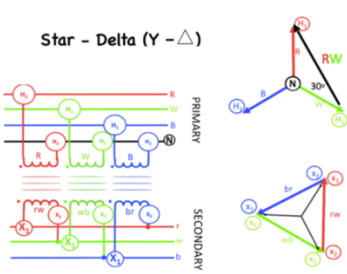
The Per Unit Equivalent



$$\frac{V_{LL}}{V_{line\text{-}line}} = \frac{V_{LL}}{V_{line\text{-}line}} = a$$

$$Z_{H\,pu} = Z_{L\,pu} \qquad \frac{I_{line}}{Prim\ I_{LINE}} = a$$

Star - Delta (Y –△)



The Primary Voltage Relationship:

$$RW = \sqrt{3}\, RN \angle 30^\circ \qquad V_{LN} = \frac{V_{LL}}{\sqrt{3}\angle 30^\circ}$$

$$V_{LL} = \sqrt{3}\, V_{LN} \angle 30^\circ$$

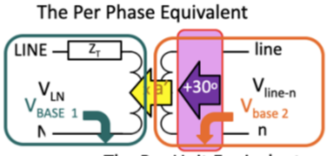
The Per Phase Turns Ratio $\quad \dfrac{V_{LN}}{V_{line\text{-}line}} = a$

$$V_{LN} = a\ V_{line\text{-}line}$$

$$V_{line\text{-}line} = \sqrt{3}\, V_{line\text{-}n} \angle 30^\circ$$

$$V_{line\text{-}n} = \frac{V_{line\text{-}line} \angle -30^\circ}{\sqrt{3}}$$

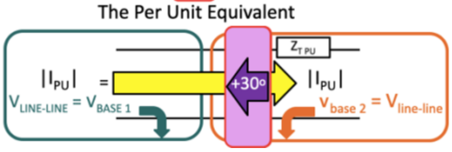
The Per Phase Equivalent



$$\frac{V_{LN}}{V_{line\text{-}n}} = \frac{a\ V_{line\text{-}line} \angle 30^\circ\ \sqrt{3}}{V_{line\text{-}line}} \qquad a' = a\sqrt{3}$$

$$\frac{V_{LL}}{V_{line\text{-}line}} = \frac{V_{LN}}{V_{line\text{-}n}} = a' \angle 30^\circ$$

The Per Unit Equivalent



$$V_{LN} = a'\, V_{line\text{-}n} \angle 30^\circ$$

$$V_{LL} = a'\, V_{line\text{-}line} \angle 30^\circ$$

$$ILine_{pri} = \frac{ILine_{sec}}{a} \angle +30^\circ$$

Phase Shift Through a (Δ-Y) Voltages Line Currents

Star - Delta (Y –△) Connected

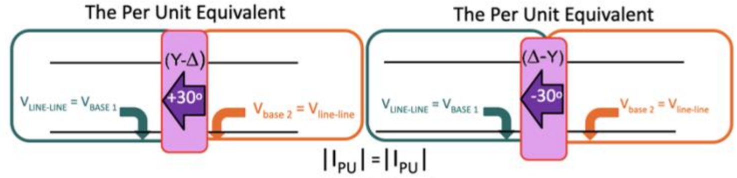
The Secondary Lags Primary by 30°

(Y-Δ) Connected Transformer Voltages Line Currents

Delta - Star (△ - Y) Connected

The Secondary Leads Primary by 30°

The Per Unit Equivalent — The Per Unit Equivalent



$$|I_{PU}| = |I_{PU}|$$

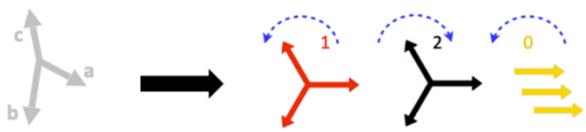
$$|V_{PU}| = |V_{PU}|$$

Cambio de Bases

$$Z_{Npu} = Z_{Mpu} \times \frac{S_{NBase}}{S_{MBase}} \times \frac{(V_{MBase})^2}{(V_{NBase})^2}$$

8) Componentes simétricos

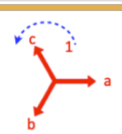
Fasores asimétricos Componentes simétricos



$$Z_a = Z_{0a} + Z_{1a} + Z_{2a}$$
$$Z_a \quad Z_b \quad Z_c \rightarrow Z_b = Z_{0b} + Z_{1b} + Z_{2b}$$
$$Z_c = Z_{0c} + Z_{1c} + Z_{2c}$$

$$V_a = V_{0a} + V_{1a} + V_{2a}$$
$$V_a \quad V_b \quad V_c \rightarrow V_b = V_{0b} + V_{1b} + V_{2b}$$
$$V_c = V_{0c} + V_{1c} + V_{2c}$$

$$I_a = I_{0a} + I_{1a} + I_{2a}$$
$$I_a \quad I_b \quad I_c \rightarrow I_b = I_{0b} + I_{1b} + I_{2b}$$
$$I_c = I_{0c} + I_{1c} + I_{2c}$$

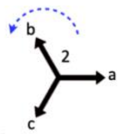


Positive Sequence

Each phasor has the same magnitude

Each positive sequence phasor quantity is displaced 120° from each another

All phasors rotate counter – clockwise giving a phase sequence of a – b – c

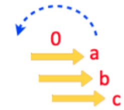


Negative Sequence

Each phasor has the same magnitude

Each negative sequence quantity is displaced 120° from one another

The negative sequence quantities have a counter clock-wise, phase rotation giving a phase sequence of a-c-b if phasors c & b are swapped



Zero Sequence

Each zero sequence phasor quantity has the same magnitude

All three phasors have no angular displacement between them, all in phase

The zero sequence phasor quantities have, counter clock-wise, phase rotation

El operador "a"

Some Properties of "a"-operator

$a = 1\angle 120^{o}$

$a^2 = 1\angle -120^{o}$ or $1\angle +240^{o}$ or $a(a)$

$a^3 = 1\angle 360^{o}$ or 1 or $1\angle 0^{o}$

$a^3 - 1 = 0$ or $0\angle 0^{o}$

$$a^{-1} = \frac{1}{a} = \frac{1}{1\angle 120^{o}} = 1\angle -120^{o} = a^2$$

$$a^{-2} = \frac{1}{\frac{1}{a}} = a$$

B-Phase Positive Sequence
We replace the Vb sequence term by the Va sequence term shifted by the "a" operator

$$Vb1 = a^2 Va1$$

B-Phase Negative Sequence
We replace the Vb sequence term by the Va sequence term shifted by the "a" operator

$$Vb2 = aVa2$$

B-Phase Zero Sequence
We replace the Vb sequence term by the Va sequence without any shift as they are in phase.

$$Vb0 = Va0$$

C-Phase Positive Sequence

We replace the Vc sequence term by the Va sequence term shifted by the "a" operator

$$Vc1 = aVa1$$

C-Phase Negative Sequence

We replace the Vc sequence term by the Va sequence term shifted by the "a" operator

$$Vc2 = a^2Va2$$

C-Phase Zero Sequence

We replace the Vc sequence term by Va sequence without any shift as they are in phase.

$$Vc0 = Va0$$

Asymmetrical Phasor Quantities → Symmetrical Components

$$Va0 = {}^1/_3 (Va + Vb + Vc)$$

$$Va1 = {}^1/_3 (Va + aVb + a^2Vc)$$

$$Va2 = {}^1/_3 (Va + a^2Vb + aVc)$$

Symmetrical Components → Asymmetrical Phasor Quantities

Symmetrical Components	Asymmetrical Phasor Quantities
$Va = Va\mathbf{0} + Va\mathbf{1} + Va\mathbf{2}$	$Va = Va\mathbf{0} + Va\mathbf{1} + Va\mathbf{2}$
$Vb = Vb\mathbf{0} + Vb\mathbf{1} + Vb\mathbf{2}$	$Vb = Va\mathbf{0} + a^2Va\mathbf{1} + aVa\mathbf{2}$
$Vc = Vc\mathbf{0} + Vc\mathbf{1} + Vc\mathbf{2}$	$Vc = Va\mathbf{0} + aVa\mathbf{1} + a^2Va\mathbf{2}$

9) Análisis de cortocircuito

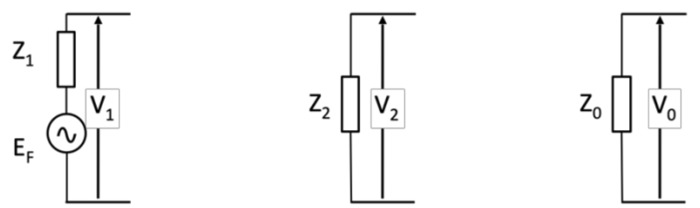
Fallas Trifásicas Asimétricas

The system only has positive sequence generators

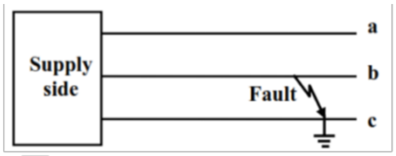
Positive Sequence Network: $V_1 = E_F - Z_1 \times I_1$

Negative Sequence Network: $V_2 = -Z_2 \times I_2$

Zero Sequence Network: $V_0 = -Z_0 \times I_0$



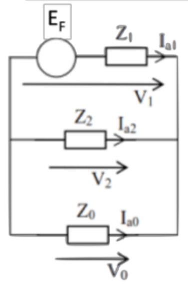
Fase a Fase a Tierra o Fallas



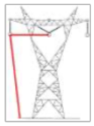
$V_b = V_c = 0$ and $I_a = 0$

$Ia_0 + Ia_1 + Ia_2 = 0 = Ia$

$Va_0 = Va_1 = Va_2$



Kirchhoff's Current Law



Fallas de línea única a tierra

$$I_f = \frac{3EF}{Z1+Z2+Z0}$$

$V_{a0} + V_{a1} + V_{a2} = 0$

$I_{a0} = I_{a1} = I_{a2}$

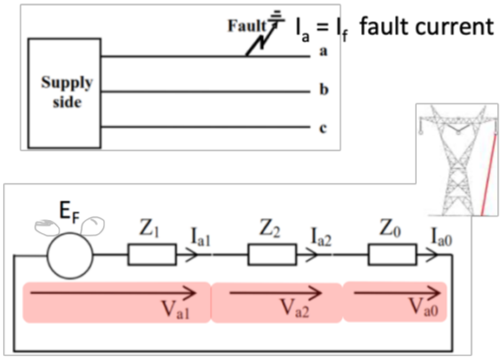
$I_f = I_a = I_{a0} + I_{a1} + I_{a2}$

$I_{a0} = I_{a1} = I_{a2} = {}^1/_3\, I_a$

$I_f = I_a = 3xI_{a0}$

$I_f = I_a = 3xI_{a1}$

$I_f = I_a = 3xI_{a2}$



Fase a tierra con impedancia

$$I_a = \frac{3EF}{Z1+Z2+Z0+3ZF} = I_F$$

$I_{a0} = I_{a1} = I_{a2}$

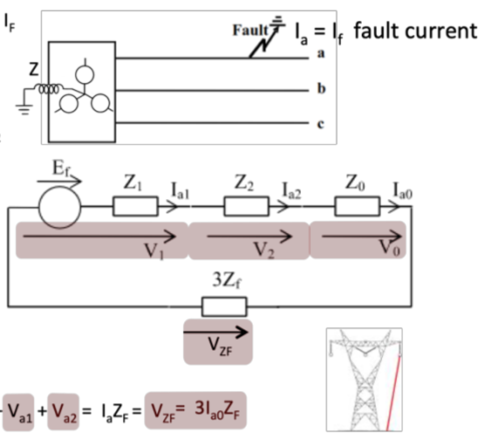
$I_f = I_a = I_{a0} + I_{a1} + I_{a2}$

$I_{a0} = I_{a1} = I_{a2} = {}^1/_3\, I_a$

$I_f = I_a = 3xI_{a0}$

$I_f = I_a = 3xI_{a1}$

$I_f = I_a = 3xI_{a2}$



$V_{a0} + V_{a1} + V_{a2} = I_a Z_F = V_{ZF} = 3I_{a0} Z_F$

Fallas fase a fase

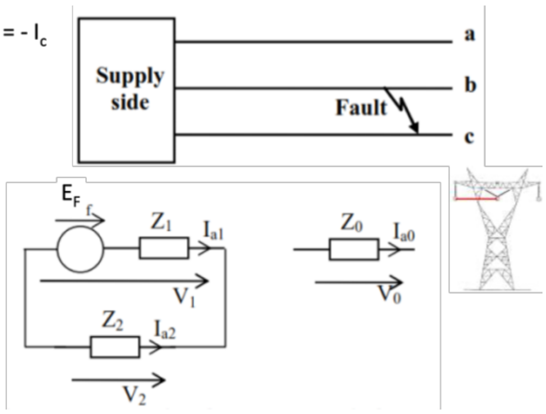
$V_b = V_c \quad I_a = 0, \quad I_b = -I_c$

$Ia_0 = 0$

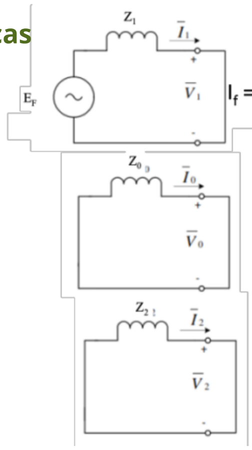
$Ia_1 = -Ia_2$

$Ia_1 + Ia_2 = 0$

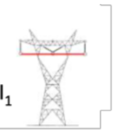
$Va_1 = Va_2$



Fallas trifásicas



$I_f = I_1$



$V_a = V_b = V_c = 0$

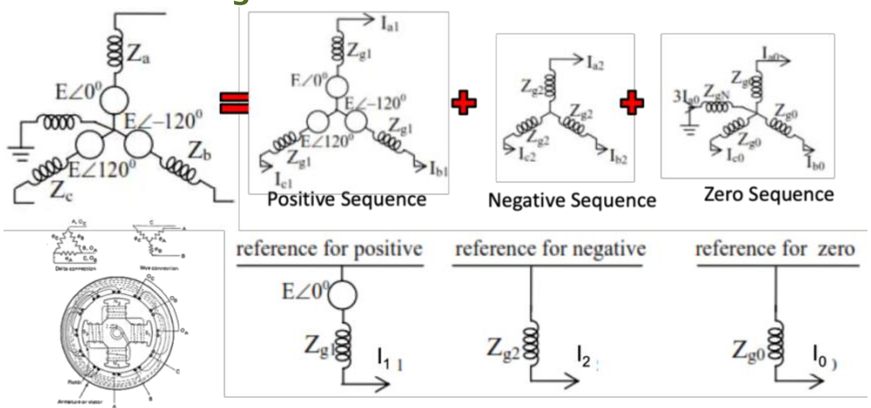
$I_a + I_b + I_c = 0$

$I_0 = I_2 = 0$

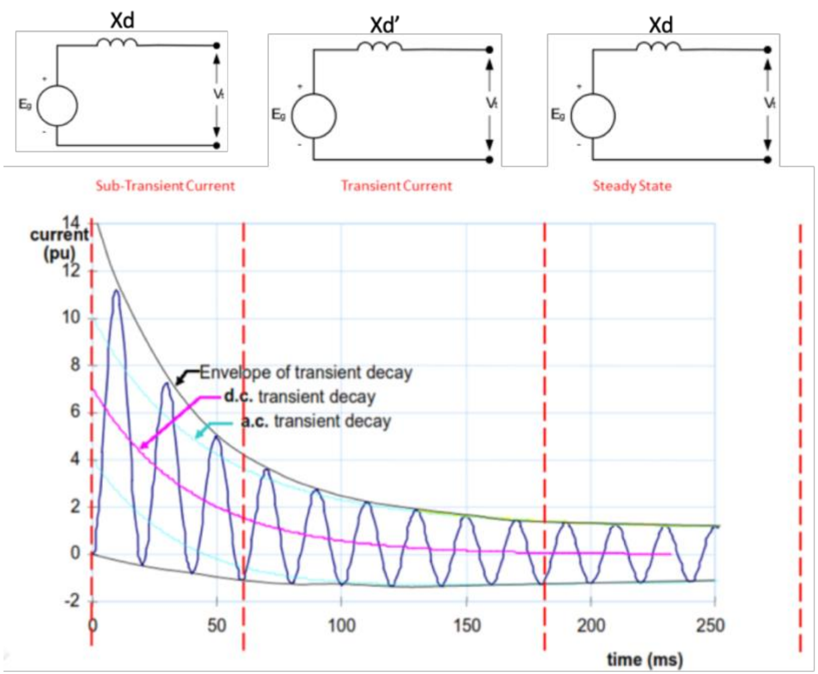
$E_F = I_{a1} \times Z_1$

Diagramas unifilares para red
Componentes

El generador



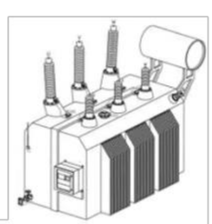
Modelado: Generadores Síncronos

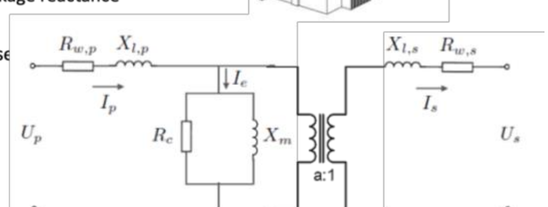


Modelado: Transformadores

Single-Line Diagrams for Network Components

- U_p = primary side terminal voltage
- U_s = secondary side terminal voltage
- $R_{w,p}$ = primary winding resistance
- $X_{l,p}$ = primary winding leakage reactance
- $R_{w,s}$ = secondary winding resistance
- $X_{l,s}$ = secondary winding leakage reactance
- X_m = magnetising reactance
- R_c = eddy current / core losses
- I_p = primary current
- I_s = secondary current
- I_e = magnetising current

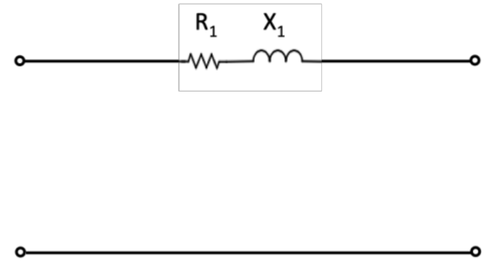




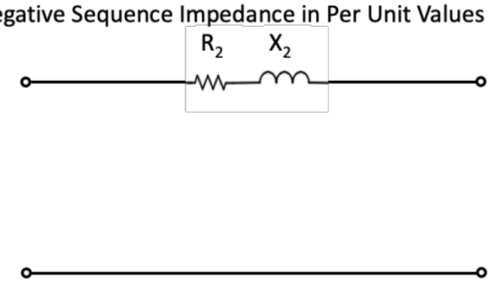
Positive & Negative Sequence Impedances

Modelado: Transformadores (continuación)

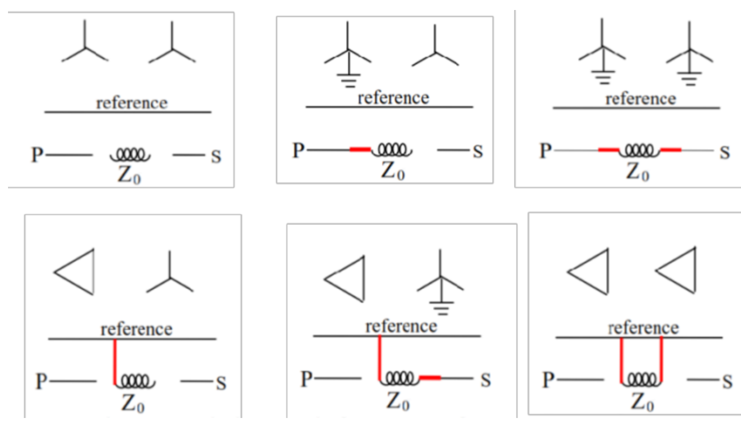
Positive Sequence Impedance in Per Unit Values



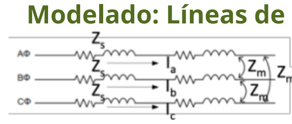
Negative Sequence Impedance in Per Unit Values



Secuencia cero a través de un transformador.



Modelado: Líneas de Transmisión



$V_a = Z_s \times I_a + Z_m \times I_b + Z_m \times I_c$

$(I_b + I_c) = -I_a$

$V_a = (Z_s - Z_m) \times I_a$

$Z_a = \frac{Va}{Ia} = (Z_s - Z_m)$

$I_{a0} = I_{b0} = I_{c0}$

$V_{a0} = Z_s \times I_{a0} + Z_m \times I_{b0} + Z_m \times I_{c0}$

$= Z_s \times I_{a0} + Z_m \times I_{a0} + Z_m \times I_{a0}$

$= Z_s \times I_{a0} + (Z_m + Z_m) \times I_{a0}$

$= (Z_s + 2Z_m) \times I_{a0}$

$Z_{a0} = \frac{Va0}{Ia0} = (Z_s + 2Z_m)$

Single-Line Diagram for Network Components

$Z_{a1} = (Z_s - Z_m)$ Positive Sequence Impedance

$Z_{a2} = (Z_s - Z_m)$ Negative Sequence Impedance

$Z_{a0} = (Z_s + 2Z_m)$ Zero Sequence Impedance

10) Protección y Control

Aparatos eléctricos

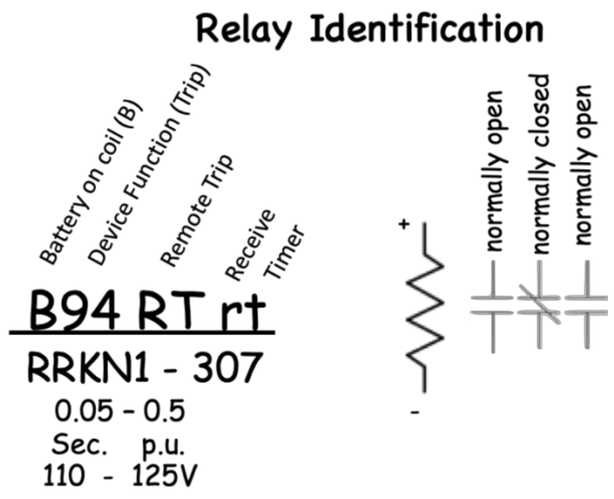
1 – Elemento maestro
2 – Retardo de tiempo de arranque o cierre del relé 3 – Relé de verificación o enclavamiento 4 – Contactor maestro
5 – Parar
6 – Disyuntor de arranque 7 – Relé de velocidad de cambio
8 – Dispositivo de desconexión de alimentación de control
9 – Dispositivo de inversión
10 – Interruptor de secuencia de unidades
11 – Dispositivo multifunción 12 – Dispositivo de exceso de velocidad
13 – Dispositivo de velocidad síncrona 14 – Dispositivo de velocidad insuficiente
15 – Velocidad – o Frecuencia, Dispositivo coincidente 16 – Dispositivo de comunicación de datos
17 – Interruptor de derivación o descarga 18 – Dispositivo de aceleración o desaceleración 19 – Contratista de transición de arranque a funcionamiento 20 – Válvula operada eléctricamente
21 – Relevo de distancia
22 – Disyuntor del ecualizador 23 – Dispositivo de control de temperatura 24 – Relé de voltios por hercio
25 – Dispositivo de sincronización o verificación de sincronización 26 – Dispositivo térmico del aparato
27 – Relé de subtensión 27s - Relé de subtensión CC 28 – Detector de llama
29 – Contactor o interruptor de aislamiento 30 – Relé anunciador
31 – Excitación separada
32 – Relé de potencia direccional o relé de potencia inversa 33 – Interruptor de posición
34 – Dispositivo de secuencia maestra
35 – Dispositivo de cortocircuito con operación de escobillas o anillo colector
36 – Dispositivos de polaridad o voltaje polarizador
37 – Relé de baja corriente o baja potencia 38 – Dispositivo protector de rodamientos
39 – Monitor de condición mecánica 40 – Relé de campo (sobreexcitación/subexcitación) 41 – Disyuntor de campo
42 – Disyuntor en funcionamiento
43 – Dispositivo selector o de transferencia manual
44 – Relé de arranque de secuencia de unidad 45 – Relé de sobretensión CC
46 – Relé de corriente de fase inversa o equilibrio de fases 47 – Relé de voltaje de secuencia de fases o equilibrio de fases 48 – Relé de secuencia incompleta
49 – Máquina o Transformador, Relé Térmico-OLR 50 – Relé de Sobrecorriente Instantánea
50G - Relé instantáneo de sobrecorriente de tierra (método CT neutro)
50N - Relé instantáneo de sobrecorriente de tierra (método residual) 50BF - Falla del disyuntor
51 – Relé de sobrecorriente de tiempo inverso de CA
51G - Relé de sobrecorriente de tierra de tiempo inverso de CA (método CT neutro) 51N - Relé de sobrecorriente de tierra de tiempo inverso de CA (método residual) 52 - Disyuntor de CA
52a - Posición del disyuntor de CA (contacto abierto cuando el disyuntor está abierto) 52b - Posición del disyuntor de CA (contacto cerrado cuando el disyuntor está abierto) 53 - Relé del excitador o del generador de CC
54 – Dispositivo de engranaje de giro 55 – Relé de factor de potencia
56 – Relé de aplicación de campo
57 – Dispositivo de cortocircuito o puesta a tierra
58 – Relé de falla de rectificación
59 – Relé de sobretensión
60 – Relé de equilibrio de voltaje o corriente 61 – Interruptor o sensor de densidad
62 – Relé Temporizado de Parada o Apertura

Números ANSI Números de función del dispositivo del sistema de energía eléctrica estándar IEEE según. según IEEE C.37.2-1991

Dispositivos eléctricos (continuación)

63 – Interruptor de presión 64 – Relé detector de tierra 64R - Falla a tierra restringida 64S - Falla a tierra del estator 65 - Gobernador

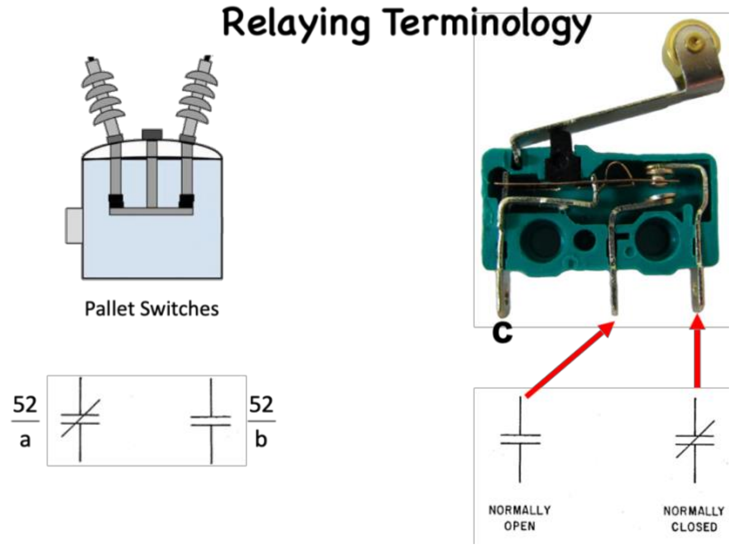
66 – Dispositivo de muesca o jogging 67 – Relé de sobrecorriente direccional de CA 68 – Relé de bloqueo
69 – Dispositivo de control permisivo 70 – Reóstato
71 – Interruptor de nivel de líquido
72 – Disyuntor de CC 73 – Contactor de resistencia de carga 74 – Relé de alarma
75 – Mecanismo de cambio de posición 76 – Relé de sobrecorriente CC
77 – Dispositivo de Telemedición
78 – Relé de medición de ángulo de fase o relé "fuera de paso" 79 – Relé de reconexión de CA (reconexión automática)
80 – Interruptor de flujo 81 – Relé de frecuencia 82 – Relé de reconexión de CC
83 – Control Selectivo Automático o Relé de Transferencia 84 – Mecanismo de Operación
85 – Comunicaciones, portadora o relé de cable piloto
86 – Relé de bloqueo/disparo maestro 87 – Relé de protección diferencial
88 – Motor auxiliar o motor generador 89 – Interruptor de línea
90 – Dispositivo de regulación 91 – Relé direccional de voltaje
92 – Relé direccional de voltaje y potencia 93 – Contactor de cambio de campo

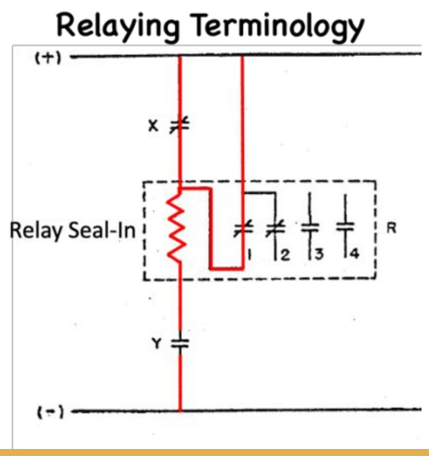


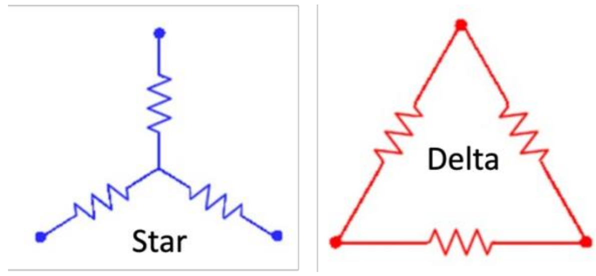
94 – Relé de disparo o disparo libre (relé de supervisión del circuito de disparo) 95 – *Para aplicaciones específicas donde otros números no son adecuados* 96 – Relé de bloqueo de disparo de barra colectora
97 – *Para aplicaciones específicas donde otros números no son adecuados* 98 – *Para aplicaciones específicas donde otros números no son adecuados* 99 – *Para aplicaciones específicas donde otros números no son adecuados* 150 – Indicador de falla a tierra AFD – Detector de arco eléctrico CLK – Fuente de reloj o temporización DDR – Registrador de perturbaciones dinámicas DFR – Registrador de fallas digital

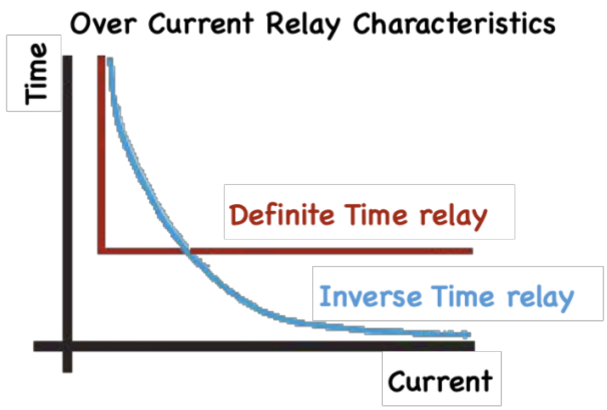
DME – Equipo de monitoreo de perturbaciones ENV – Datos ambientales HIZ – Detector de fallas de alta impedancia HMI – Interfaz hombre-máquina HST – Historiador
LGC – Lógica de esquema MET – Medición de subestaciones PDC – Concentrador de datos fasoriales PMU – Unidad de medición fasorial PQM – Monitor de calidad de energía RIO – Dispositivo remoto de entrada/salida
RTU – Unidad Terminal Remota/Concentrador de Datos
SER – Registrador de Secuencia de Eventos
TCM – Monitor de circuito de disparo
LRSS - INTERRUPTOR SELECTOR LOCAL/REMOTO
SOTF - Encendido hasta falla

Números ANSI Números de función del dispositivo del sistema de energía eléctrica estándar IEEE según. según IEEE C.37.2-1991









Liquid Cooled Transformers

First letter: Internal cooling medium in contact with the windings

- **O** mineral oil or synthetic insulating liquid with fire point < 300°C
- **K** insulating liquid with fire point > 300°C
- **L** insulating liquid with no measurable fire point

Second letter: Circulation mechanism for internal cooling medium:

- **N** natural convection flow through cooling equipment and windings
- **F** forced circulation through cooling equipment (cooling pumps)
- **D** forced circulation through cooling equipment, directed from the cooling equipment into at least the main windings

Third letter: External cooling medium

- **A** air
- **W** water

Fourth letter: Circulation mechanism for external cooling medium

- **N** natural convection
- **F** forced circulation (fans, pumps)

ONAF Cooling of Transformer "Oil Natural Air Forced"

ONAN Cooling of Transformer "Oil Natural Air Natural"

OFAF Cooling of Transformer "Oil Forced Air Forced"

OFWF Cooling of Transformer "Oil Forced Water Forced"

Esquemas de relés de protección

Differential Protection: Generators, Transformers, Lines & Buses

Pilot Wire Protection: Short Lines

Impedance Protection: Long Lines

(a) Two zone distance protection
(b) Phase comparison protection
(c) Directional comparison protection
(d) Direct under-reaching protection
(e) Permissive overreaching protection

Co-ordinated Over-Current Protection: Feeders

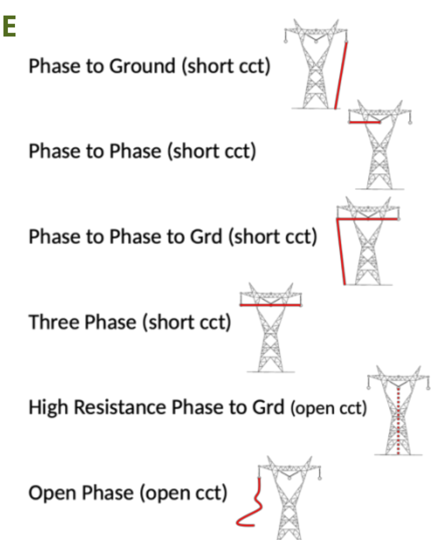
Breaker failure protection

CT and breaker flash protection

Remote Trip: Short Distances

Transfer Trip: Long Distances

Tipos de E



Esquemas de relés de protección

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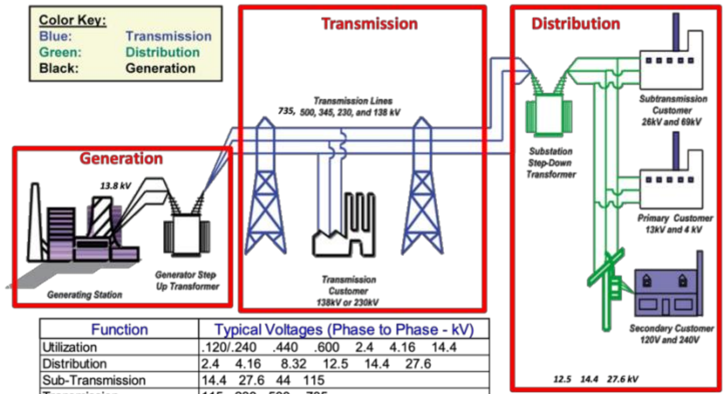
Transfer Trip: Long Distances

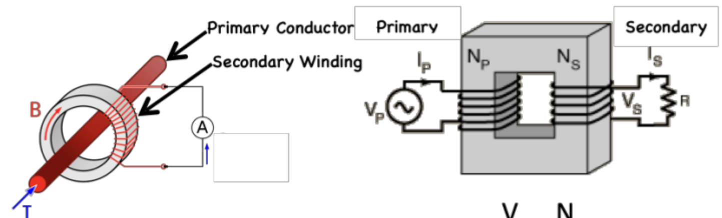
Estructura básica del sistema eléctrico



Function	Typical Voltages (Phase to Phase - kV)
Utilization	.120/.240 .440 .600 2.4 4.16 14.4
Distribution	2.4 4.16 8.32 12.5 14.4 27.6
Sub-Transmission	14.4 27.6 44 115
Transmission	115 230 500 735
Transformation	Transformation Between voltage levels
System Machines (synchronous condensers frequency changers, etc.)	12.5 - 14.4
Generation	2.4 4.16 13.8 - 24.0

Transformadores de instrumentos

Two Types



$$I_P N_P = I_S N_S$$

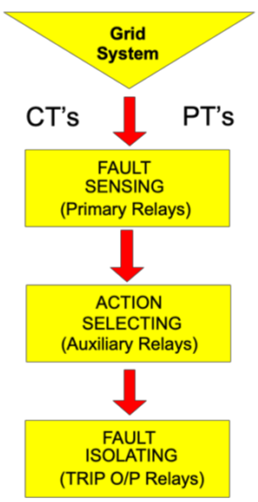
$$I_S = I_P \frac{N_P}{N_S} \quad \text{If } N_P \text{ is} = 1$$

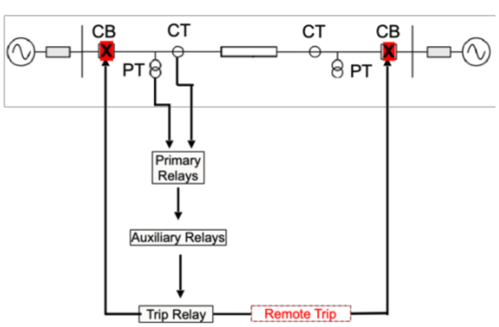
$$I_S = \frac{I_P}{N_S}$$

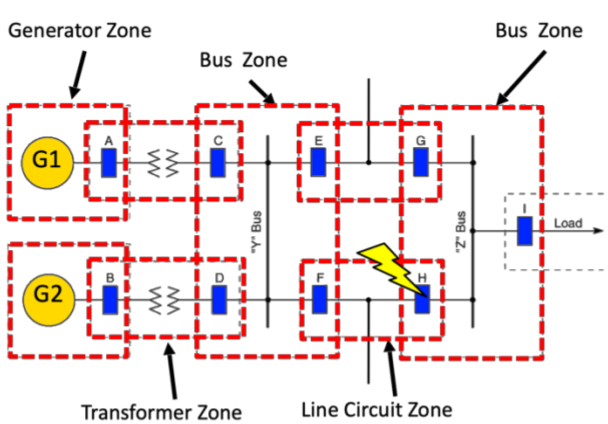
$$\frac{V_s}{V_p} = \frac{N_s}{N_p}$$

Elementos de una protección

Esquema de retransmisión

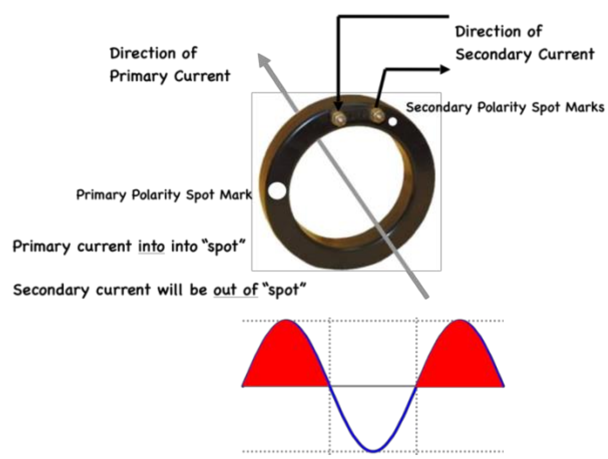




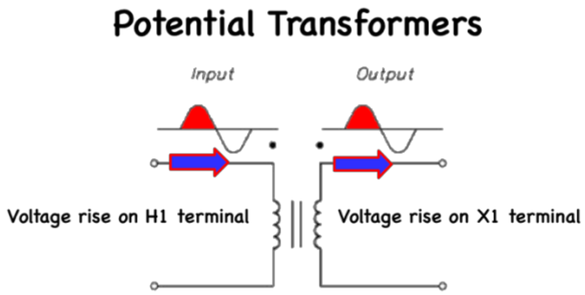


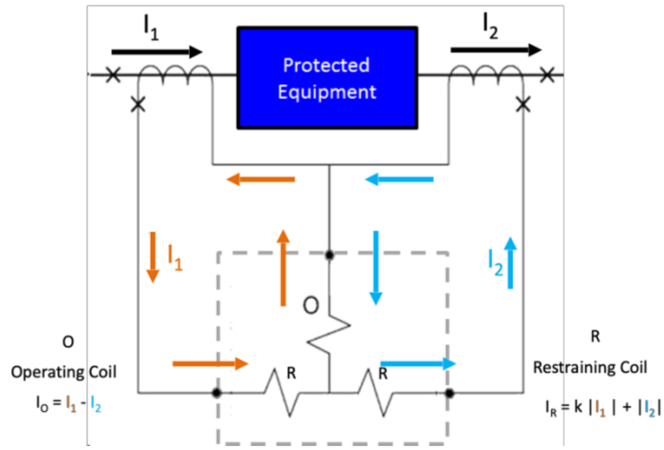
Polaridad

Current Transformers



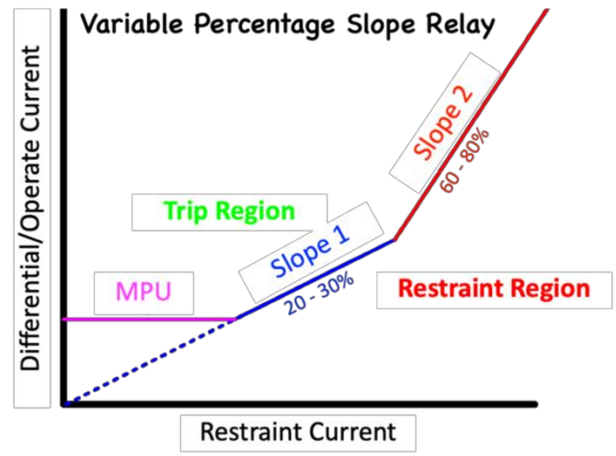
Polaridad (continuación)



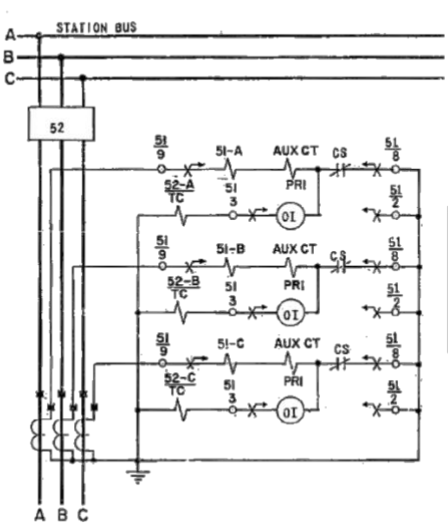


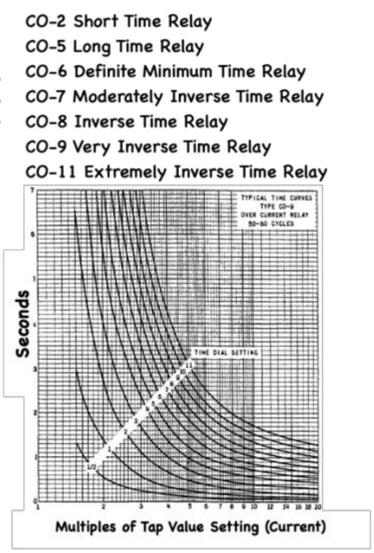
Tipos de disyuntores de alta tensión

- Oil Breakers
- Minimum Oil Breakers
- Vacuum Breakers
- SF6 Breakers
- Air Blast Breakers

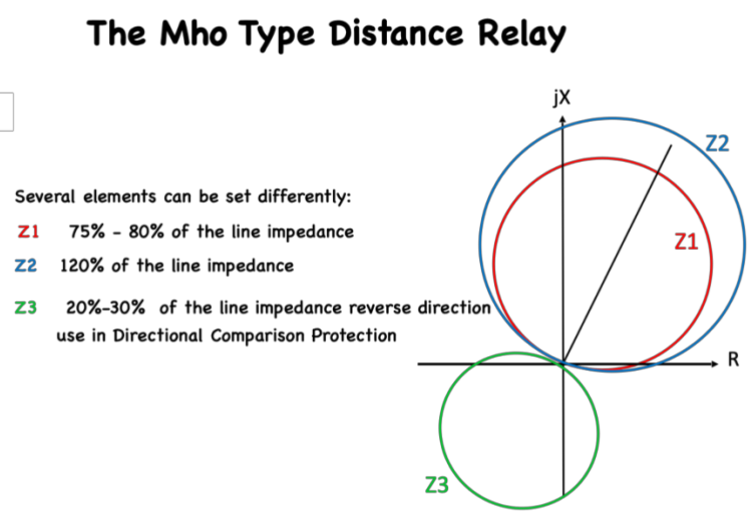


Westinghouse (ABB)

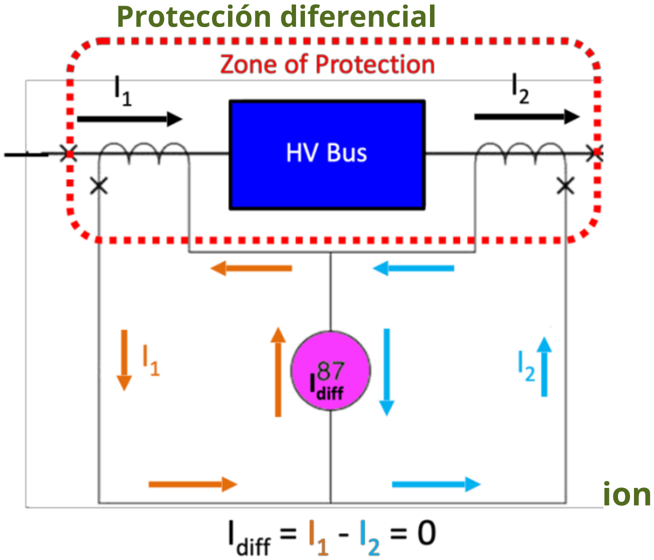




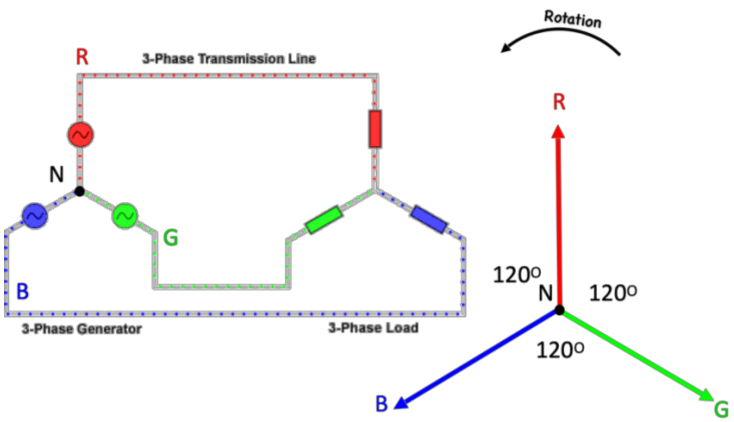
Retransmisión de impedancia



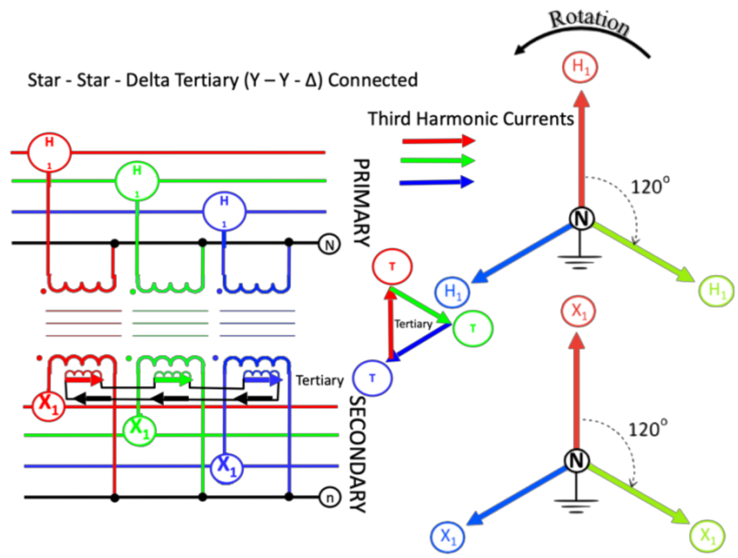
Protección diferencial



11) Transformadores Trifásicos

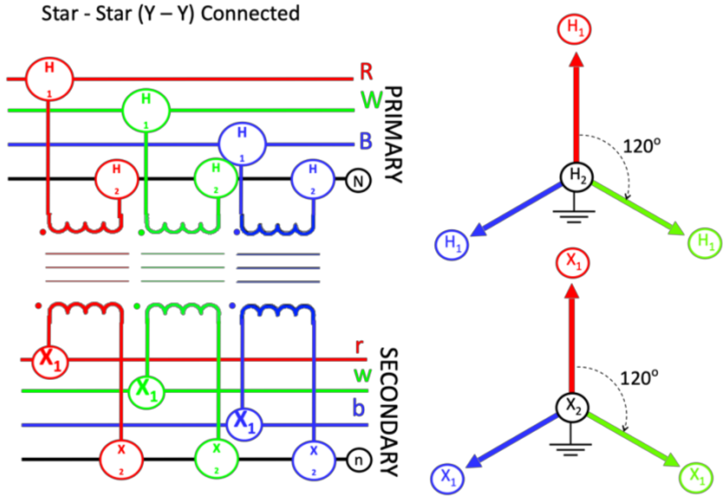


Star - Star - Delta Tertiary (Y – Y - Δ) Connected

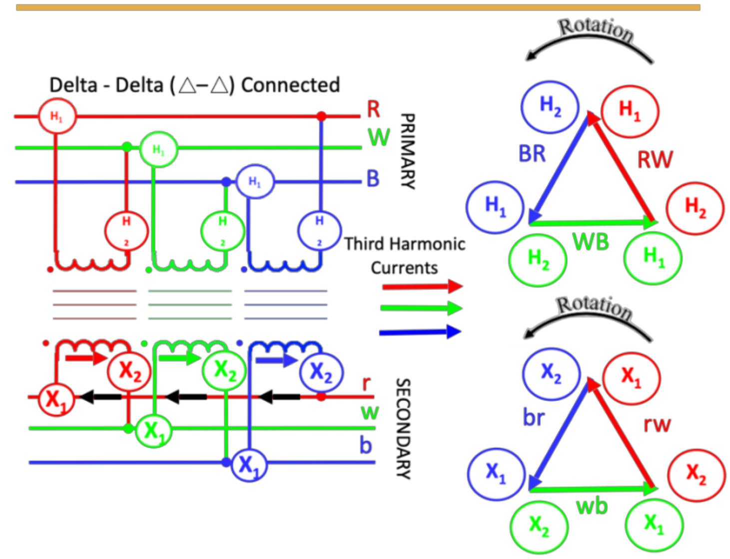


Conexiones del transformador

Star - Star (Y – Y) Connected



Delta - Delta (△–△) Connected



The 3rd Harmonic

Fundamental Frequency is **sin(ωt)**

3rd Harmonic is Frequency is **sin 3x(ωt)**

$A = A\sin(\omega t + 0°)$

$B = B\sin(\omega t + 120°)$

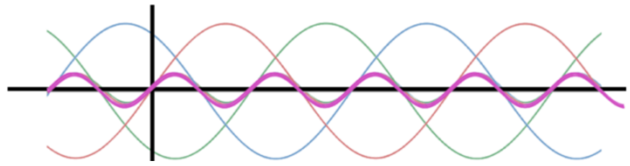
$W = W\sin(\omega t - 120°)$

$A_{(3\,H)} = A_{(3\,H)}\sin 3(\omega t + 0°) = A_{(3\,H)}\sin(3\omega t + 3x0°) = A_{(3\,H)}\sin(3\omega t)$

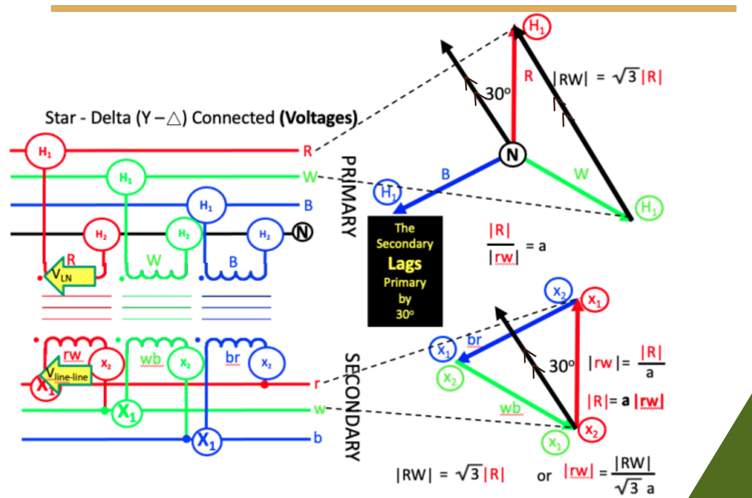
$B_{(3\,H)} = B_{(3\,H)}\sin 3(\omega t + 120°) = B_{(3\,H)}\sin(3\omega t + 360°) = B_{(3\,H)}\sin(3\omega t)$

$W_{(3\,H)} = W_{(3\,H)}\sin 3(\omega t - 120°) = W_{(3\,H)}\sin(3\omega t - 360°) = W_{(3\,H)}\sin(3\omega t)$

In Phase

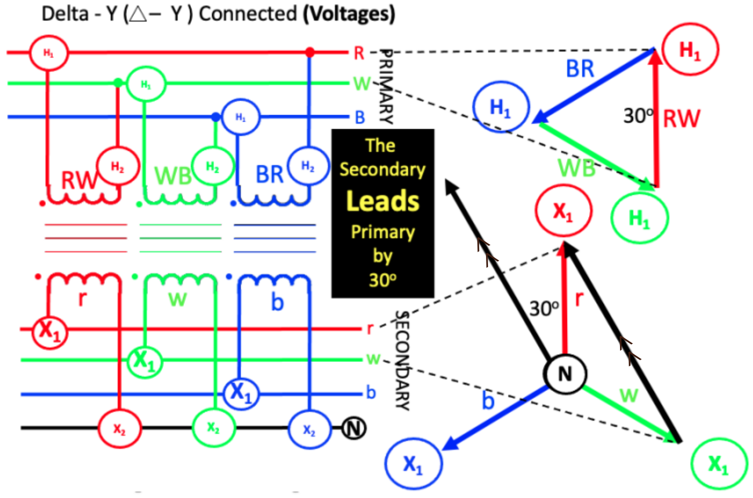


Star - Delta (Y – △) Connected (**Voltages**)

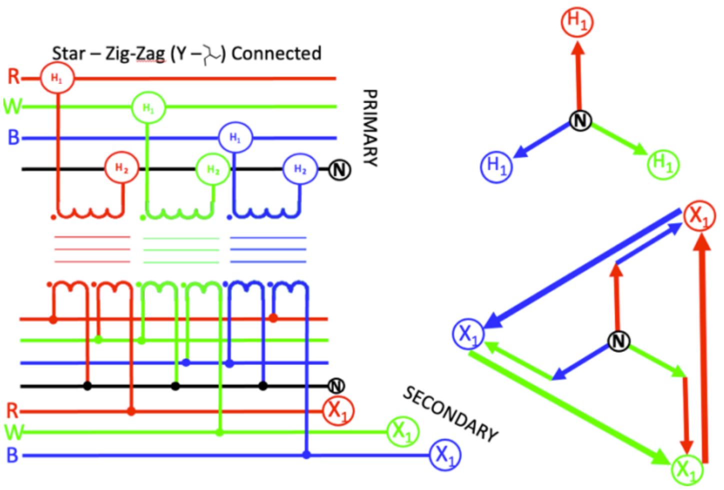


Conexiones del transformador (continuación)

Delta - Y (△– Y) Connected **(Voltages)**



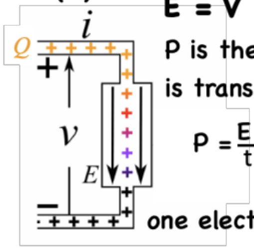
Star – Zig-Zag (Y –) Connected



12) Medición

Poder y energía

Work done or electric energy (E) is the movement of charge (Q) caused by EMF (V)



$$E = V \times Q$$

P is the rate at which electric energy (E) is transferred by an electric circuit

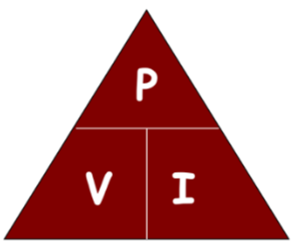
$$P = \frac{E}{t} = \frac{VQ}{t} = V \times Q/t = V \times I$$

one electron = $1/Q = 1.6 \times 10^{-19}$ coulombs

1 coulomb = 6,250,000,000,000,000,000 electrons

1 amp = 1 coulomb passing by in 1 second of time

Electrical power is measured in **Watts** (symbol: **W**)



$$P = V\,I \text{ watts}$$

$$V = \frac{P}{I} \text{ volts}$$

$$I = \frac{P}{V} \text{ amps}$$

Energía eléctrica

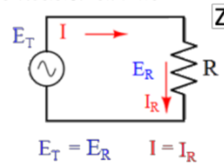
Energy = Power x Time

Joule (J)
Watt hour
Watt Sec
kilowatt hour

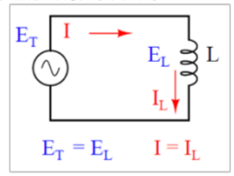
SI multiples for watt hour (W·h)

Submultiples			Multiples		
Value	Symbol	Name	Value	Symbol	Name
10^{-3}	mW·h	milliwatt hour	10^{3}	kW·h	kilowatt hour
10^{-6}	μW·h	microwatt hour	10^{6}	MW·h	megawatt hour
			10^{9}	GW·h	gigawatt hour
			10^{12}	TW·h	terawatt hour
			10^{15}	PW·h	petawatt hour

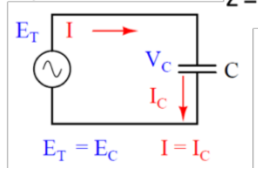
AC Resistor Circuits

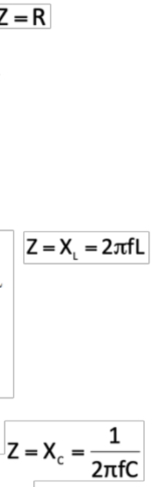


AC Inductor Circuits



AC Capacitive Circuits





$$V_{rms} = \frac{V_{Peak}}{\sqrt{2}} = 0.707\,V_{Peak}$$

$$I_{AC} = I_{RMS} = 0.707\,I_{Peak}$$

$$\text{Average } P_{DC} = \text{Average } P_{AC}$$

$$P_{Avg} = I_{rms}^2 R \quad \text{watts}_{avg}$$

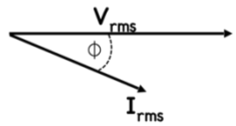
$$P_{Avg} = \frac{V_{RMS}^2}{R} \quad \text{watts}_{Avg}$$

$$P_{Avg} = V_{rms}\,I_{rms} \quad \text{watts}_{avg}$$

$$V_{rms} = \frac{P_{Avg}}{I_{rms}} \quad \text{volts}_{RMS}$$

$$I_{rms} = \frac{P_{Avg}}{V_{rms}} \quad \text{amps}_{RMS}$$

Energia electrica



$$P_{avg} = \frac{V_m I_m}{2} \cos(\phi)$$

$$P_{avg} = \frac{V_m}{\sqrt{2}} \times \frac{I_m}{\sqrt{2}} \cos(\phi)$$

but $V_{rms} = \frac{V_m}{2}$ And

then $P_{avg} = V_{rms} \times I_{rms} \cos(\phi)$

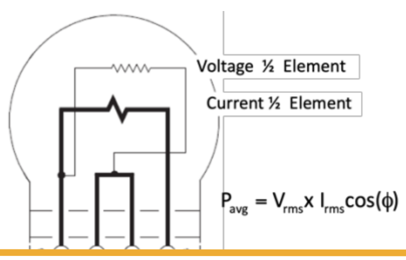
$$P_{avg} = \frac{V_m I_m}{2} \cos(\phi)$$

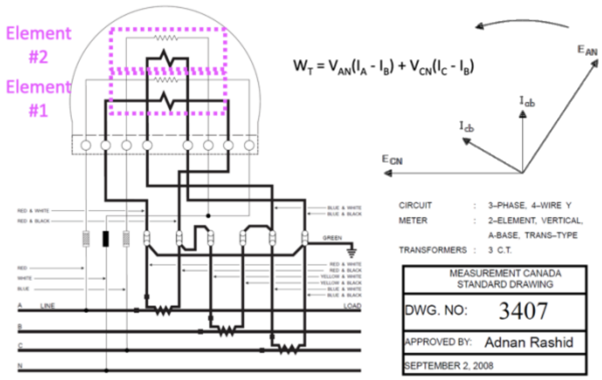
$$P_{avg} = V_{rms} \times I_{rms} \cos(\phi)$$

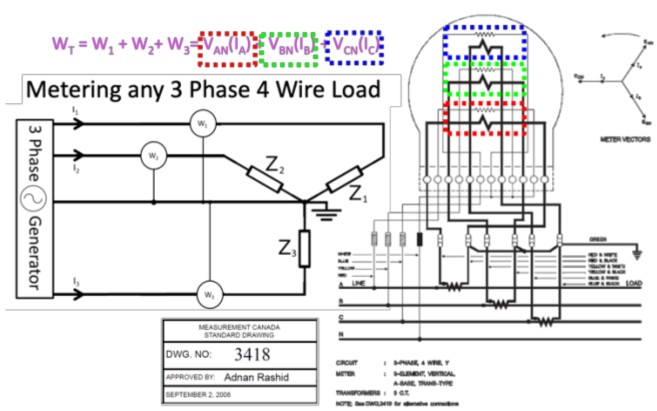
$$Q_{avg} = V_{rms} \times I_{rms} \sin(\phi) \text{ VARs}$$

$$\text{Apparent Power} = V_{rms} \times I_{rms} \text{ VA}$$

Contadores de vatios hora







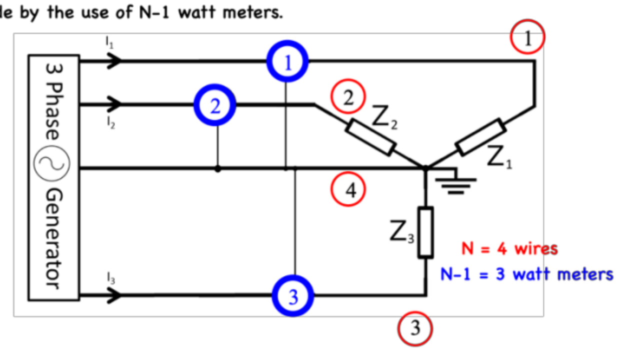
Especificaciones del sitio WEB de Industry Canada para medidores de electricidad

Industry Canada's WEB Site has the Specifications for the Installation and Use of Electricity Meters along with Measurement Canada Standard Drawings for Electricity Metering Installations including Colour Coded Connections

http://www.ic.gc.ca/eic/site/mc-mc.nsf/eng/lm04068.html#AppendixII

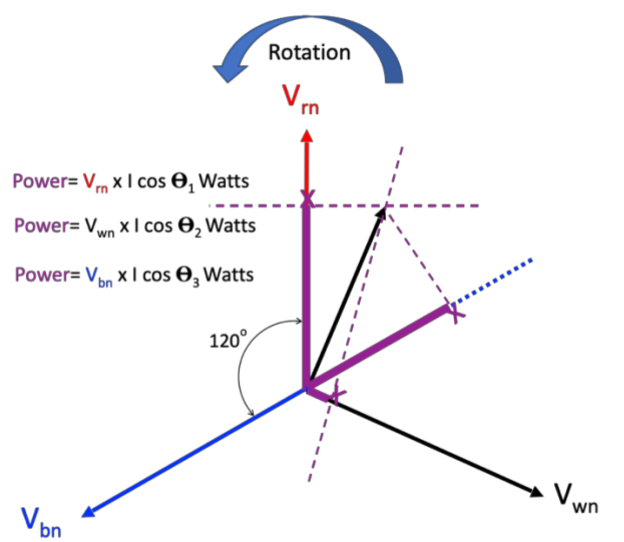
Teorema de Blondel

If energy is supplied to any system of conductors through N wires, the total power in the system is given by the algebraic sum of the readings of N watt meters, so arranged that each of the N wires contains one current coil, the corresponding voltage coil being connected between that wire and some common point. If this common point is on one of the N wires, the measurement may be made by the use of N-1 watt meters.



Verificación del vatímetro cruzado

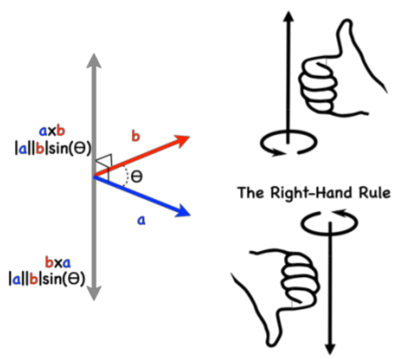
V_{rn} V_{wn} V_{bn}
Are reference phasors which are equal in magnitude and 120° apart



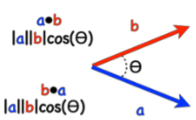
13) Máquinas Rotativas

Máquinas de corriente continua

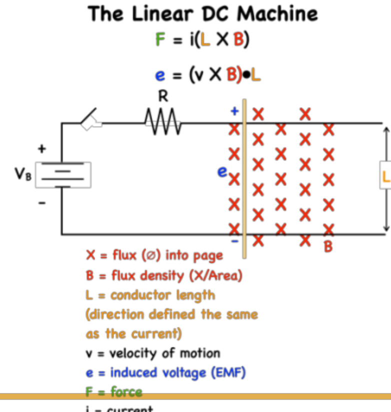
The Cross Product of Two Vectors



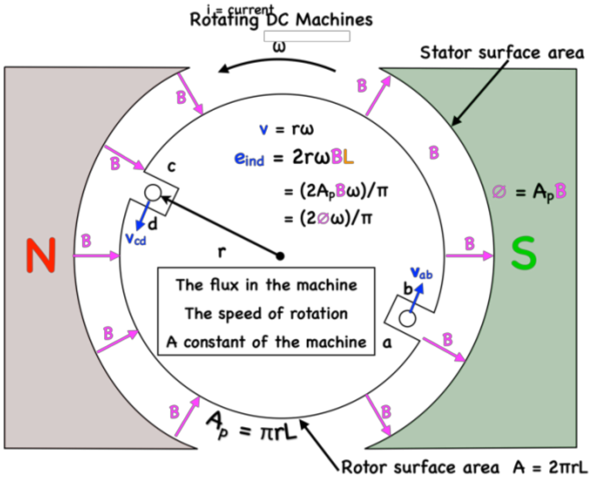
The Dot Product of Two Vectors



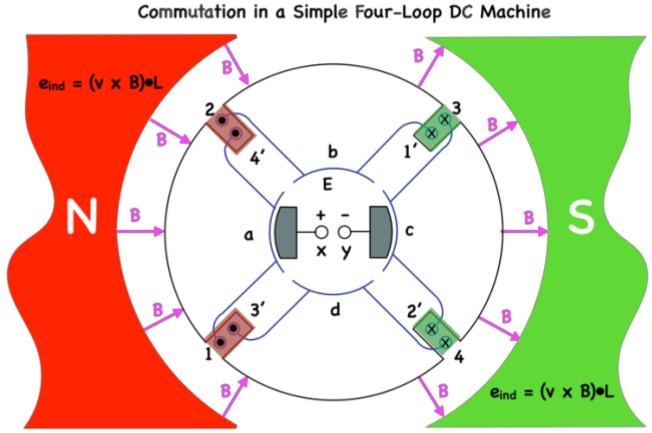
The Linear DC Machine



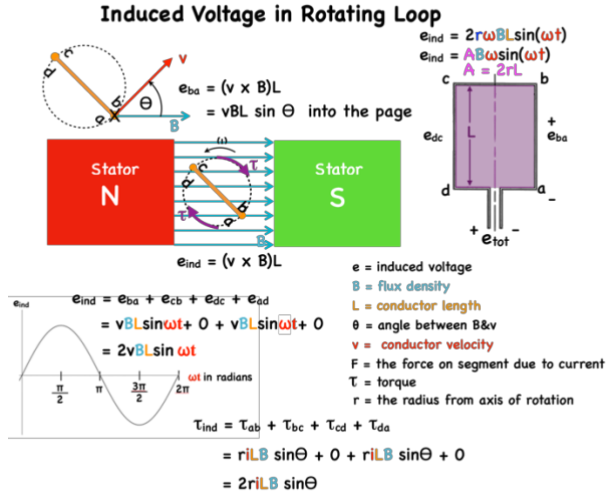
Rotating DC Machines



Commutation in a Simple Four-Loop DC Machine

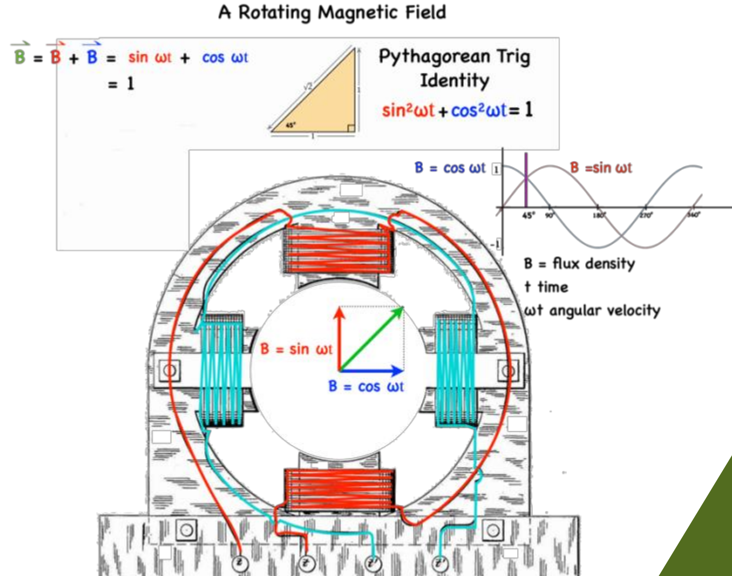


Induced Voltage in Rotating Loop

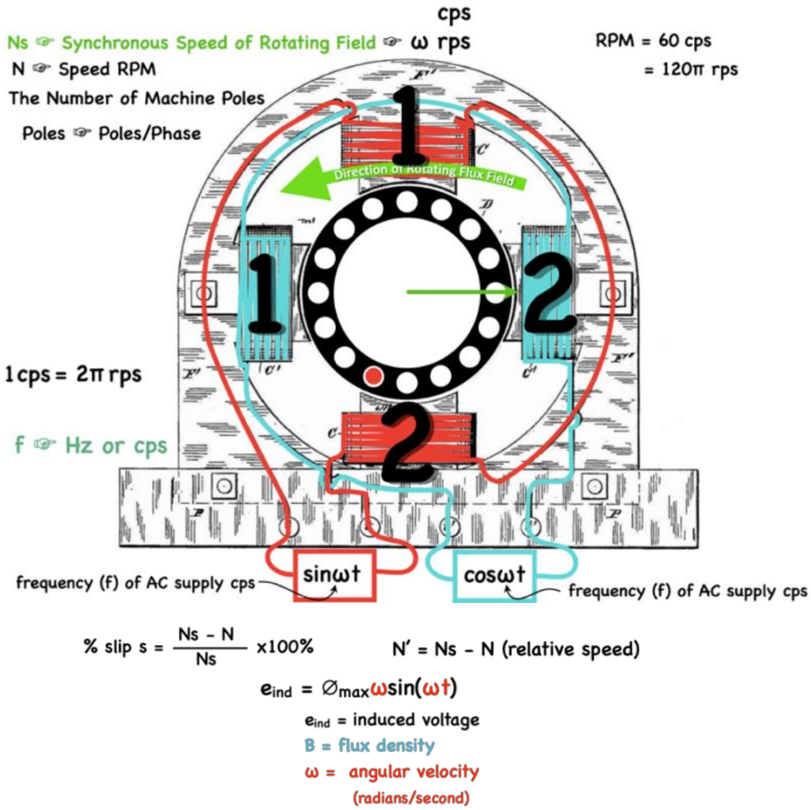


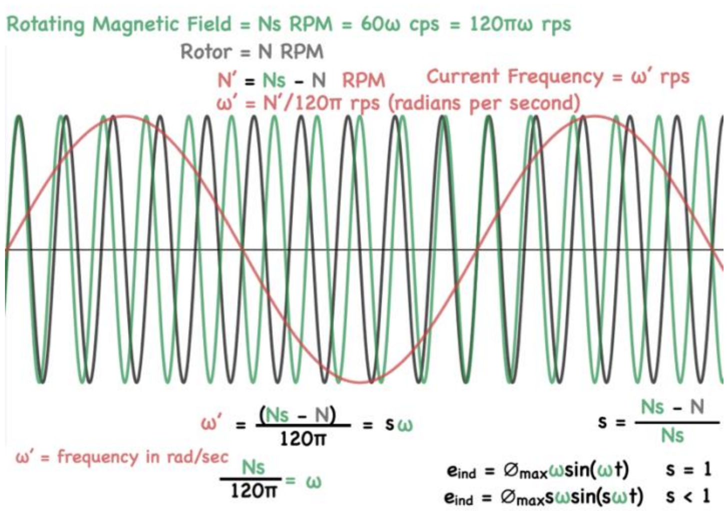
El motor de inducción

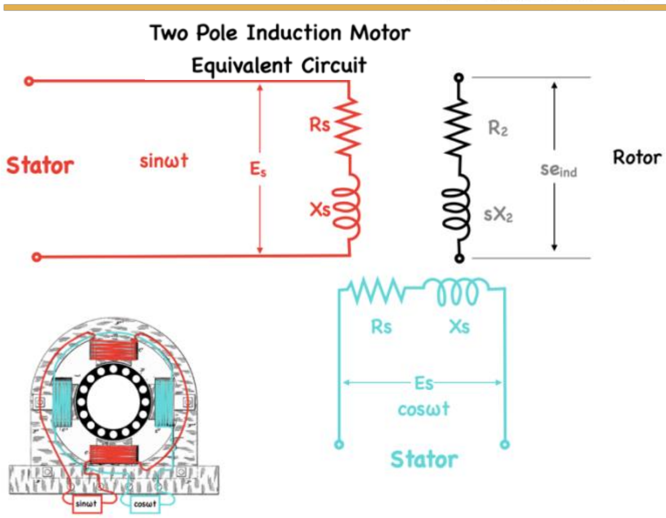
A Rotating Magnetic Field



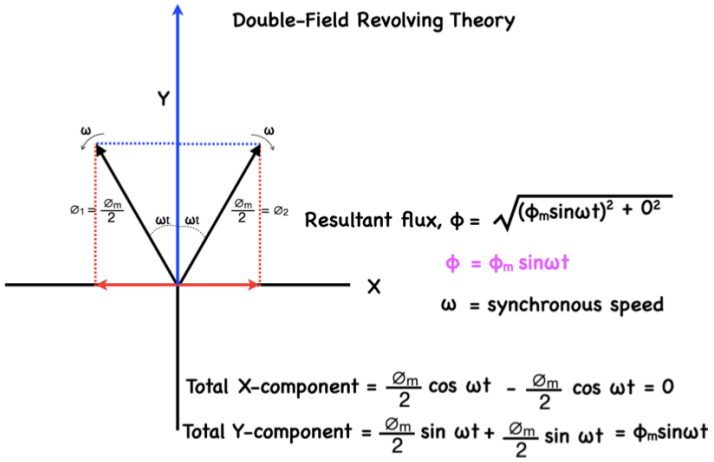
Rotores de motores de inducción

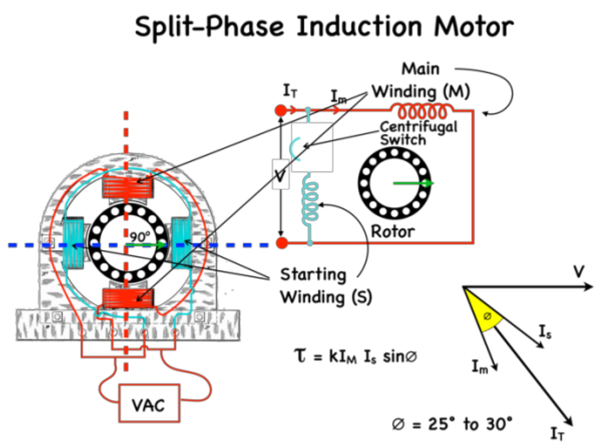


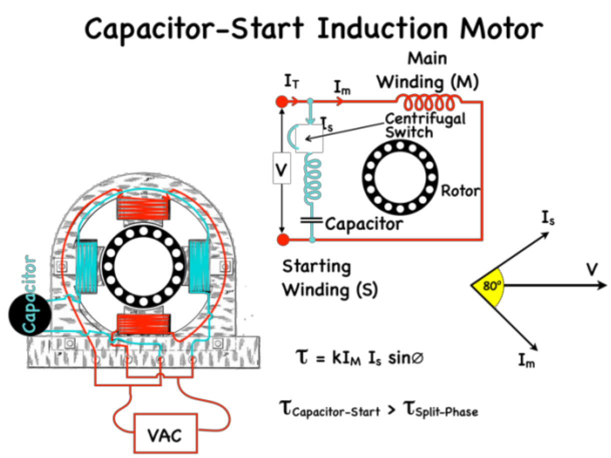




Motores de inducción monofásicos







Motores de inducción trifásicos

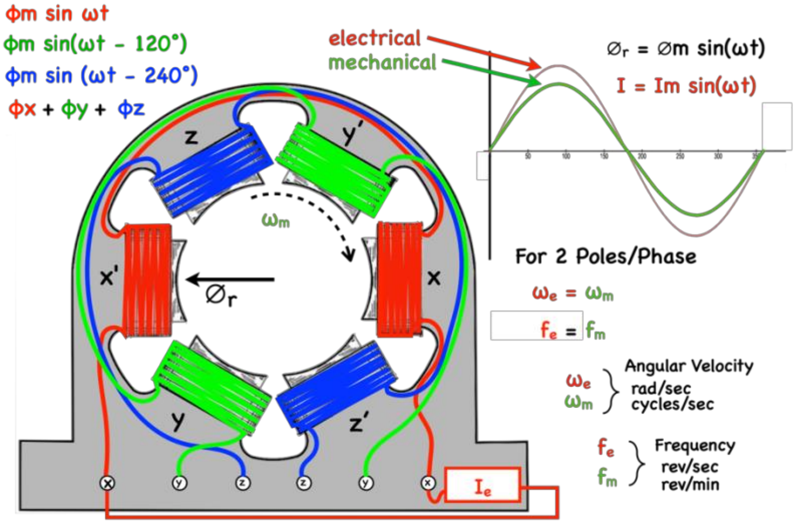
Electrical Frequency and the Speed of Magnetic Field Rotation

$\phi x = \phi m \sin \omega t$

$\phi y = \phi m \sin(\omega t - 120°)$

$\phi z = \phi m \sin(\omega t - 240°)$

$\phi r = \phi x + \phi y + \phi z$



Rotating Stator Field Speed = N_S

Rotor Speed = N

Ns – N ☞ slip speed

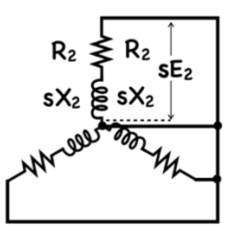
$$\text{slip } s = \frac{Ns - N}{Ns}$$

$$\%\text{ slip } s = \frac{Ns - N}{Ns} \times 100\%$$

A stationary rotor (N = 0)

slip, s = 1 or 100 %

Rotor Current



At standstill

Rotor current/phase $I_2 = \frac{E_2}{Z_2} = \frac{E_2}{\sqrt{(R_2)^2 + (X_2)^2}}$

Rotor P. F. $\cos \varnothing_2 = \frac{R_2}{Z_2} = \frac{R_2}{\sqrt{(R_2)^2 + (X_2)^2}}$

When running at slip s

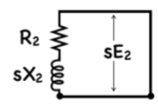
Rotor current/phase $I'_2 = \frac{sE_2}{Z'_2} = \frac{sE_2}{\sqrt{(R_2)^2 + (sX_2)^2}}$

Rotor P. F. $\cos \varnothing'_2 = \frac{R_2}{Z'_2} = \frac{R_2}{\sqrt{(R_2)^2 + (sX_2)^2}}$

Rotor Torque

The torque τ developed by the rotor is directly proportional to:

- rotor current I_2
- rotor e.m.f. E_2
- power factor of the rotor circuit $\cos \varnothing_2$



I2 = rotor current

E2 = rotor e.m.f.

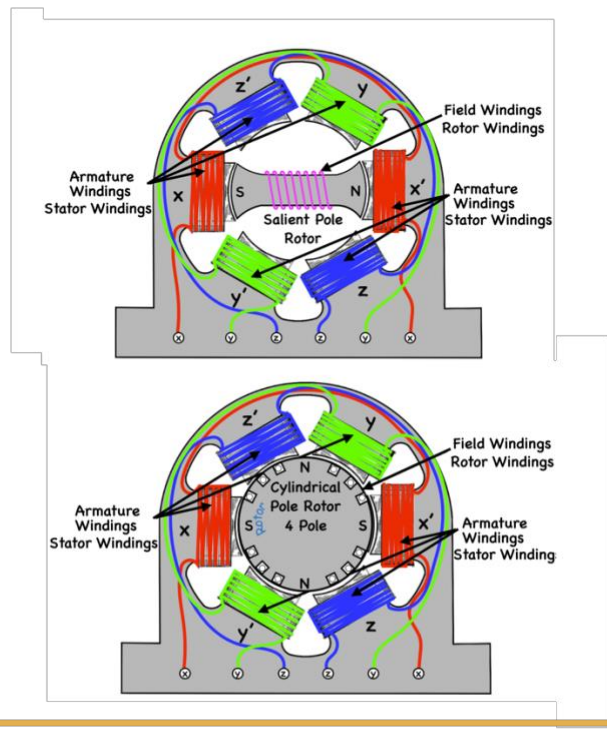
cos ϕ2 = rotor p.f.

$\therefore \quad \tau \propto E_2 I_2 \cos \phi_2$

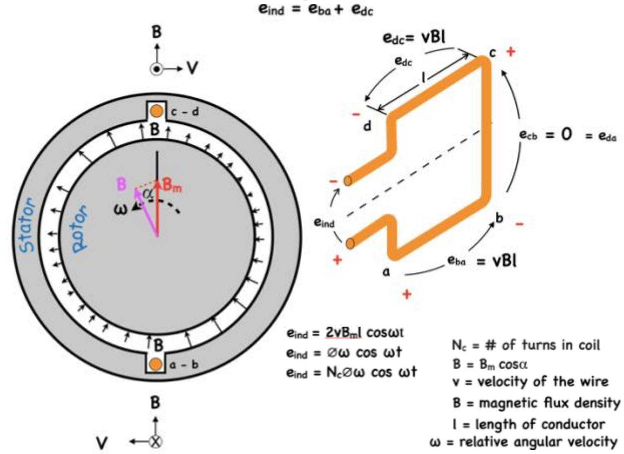
or $\quad \tau = K E_2 I_2 \cos \phi_2$

Since at standstill $I_2 = \frac{E_2}{\sqrt{(R_2)^2 + (X_2)^2}}$ and $\cos \varnothing_2 = \frac{R_2}{\sqrt{(R_2)^2 + (X_2)^2}}$ at standstill

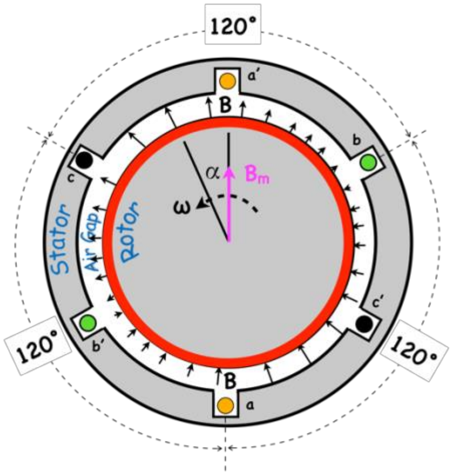
Then at standstill $\tau = KE_2 \times \frac{E_2}{\sqrt{(R_2)^2 + (X_2)^2}} \times \frac{R_2}{\sqrt{(R_2)^2 + (X_2)^2}} = \frac{K(E_2)^2 R_2}{(R_2)^2 + (X_2)^2}$



Three-Phase Induced Voltages



Three-Phase Induced Voltages (Cont'd)



$e_{aa'}(t) = N_C \varnothing \omega \cos \omega t$

$e_{bb'}(t) = N_C \varnothing \omega \cos (\omega t - 120°)$

$e_{cc'}(t) = N_C \varnothing \omega \cos (\omega t - 240°)$

$E_{max} = N_C \varnothing \omega$

Since $\omega = 2\pi f$ f ☞ CPS

$E_{max} = 2 N_C \varnothing \pi f$

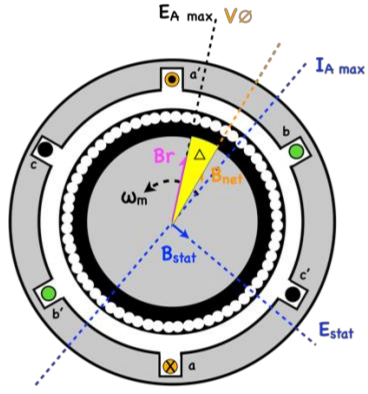
Magnitude

$|E_A| = \frac{2\pi}{\sqrt{2}} N_C \varnothing f$

$|E_A| = \sqrt{2}\, \pi N_C \varnothing f$

f ☞ cps of magnetic field

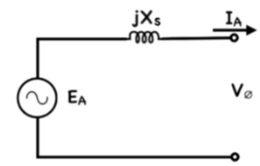
El circuito equivalente de un Generador síncrono



Armature (stator) Reaction

$E_{stat} = -jXI_A$

$V_\varnothing = E_A - jXI_A$



$V_\varnothing = E_A + E_{stat}$

$B_{net} = B_r + B_{stat}$

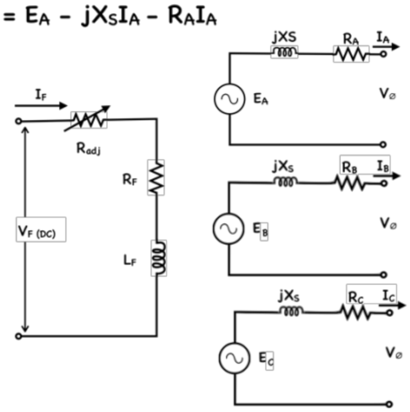
Stator self inductance jX_A

Stator resistance R_A

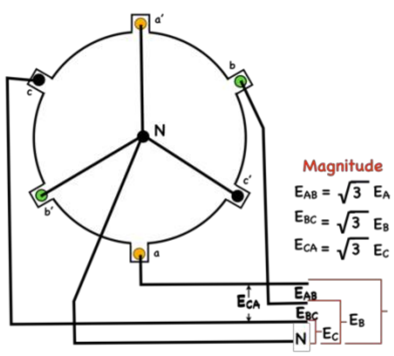
$V_\varnothing = E_A - jX_A I_A - jX_A I_A - R_A I_A$

$X_S = X + X_A$

$V\varnothing = E_A - jX_S I_A - R_A I_A$



Y-Connected



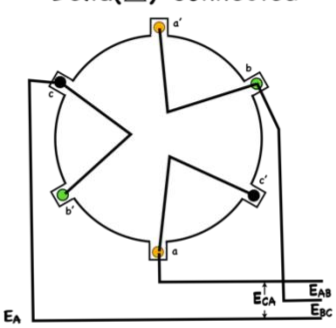
Magnitude

$E_{AB} = \sqrt{3}\, E_A$

$E_{BC} = \sqrt{3}\, E_B$

$E_{CA} = \sqrt{3}\, E_C$

Delta(△)-Connected



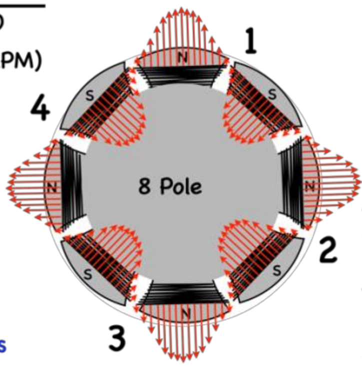
Rotor Speed = f cps

Induced Voltage Frequency of an P Pole Rotor = $\frac{P}{2}$ x f cps

$f_e \text{ (cps)} = \frac{P}{2} f_R \text{ (cps)}$

$f_e \text{ (cps)} = \frac{P}{2} \frac{f_R \text{ (RPM)}}{60}$

$f_e \text{ (cps)} = \frac{P}{120} f_R \text{ (RPM)}$

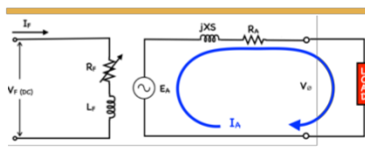


As the rotor completes one cycle the induced stator voltage coil will go through 1/2 the number of cycles as there are pole on the rotor.

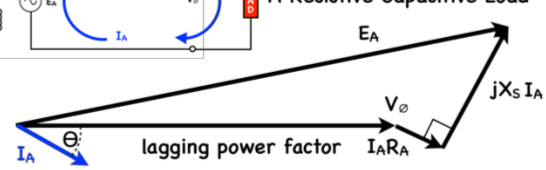
P = number of poles

f_e = electrical frequency, in Hz (cps)

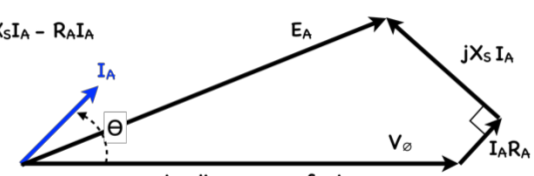
f_R = mechanical speed of the rotor



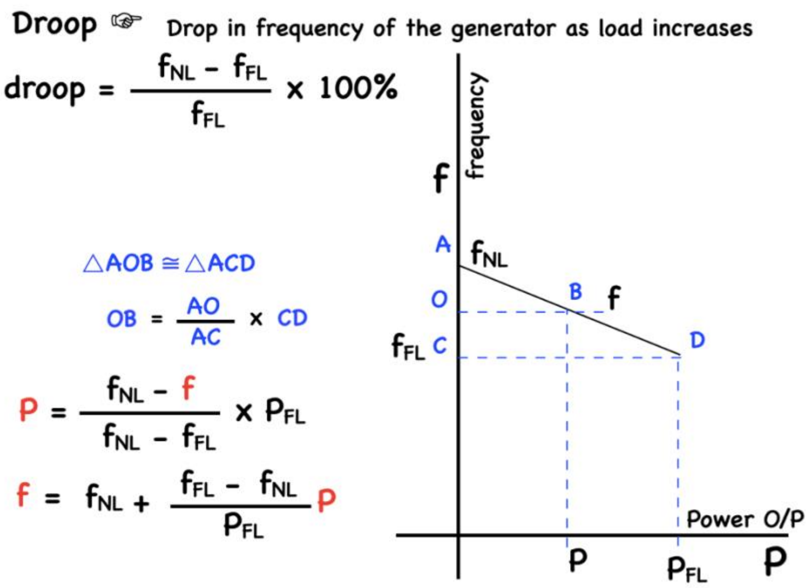
A Resistive Capacitive Load



$V\varnothing = E_A - jX_S I_A - R_A I_A$



The Phasor Diagram of a Synchronous Generator

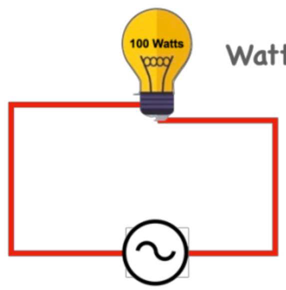

Droop ☞ Drop in frequency of the generator as load increases
droop = (fNL − fFL) / fFL x 100%
frequency
f
A
fNL
△AOB ≅ △ACD
O
B
f
OB = AO/AC x CD
fFL
C
D
P = (fNL − f) / (fNL − fFL) x PFL
f = fNL + (fFL − fNL) / PFL P
Power O/P
P
PFL
P

14) Cableado eléctrico de bajo voltaje

All electrical circuits have:

1) Voltage, 2) Current and 3) Resistance 4) Watts

$$\text{Current} = \frac{\text{Voltage}}{\text{Resistance}} \qquad I = \frac{V}{R}$$



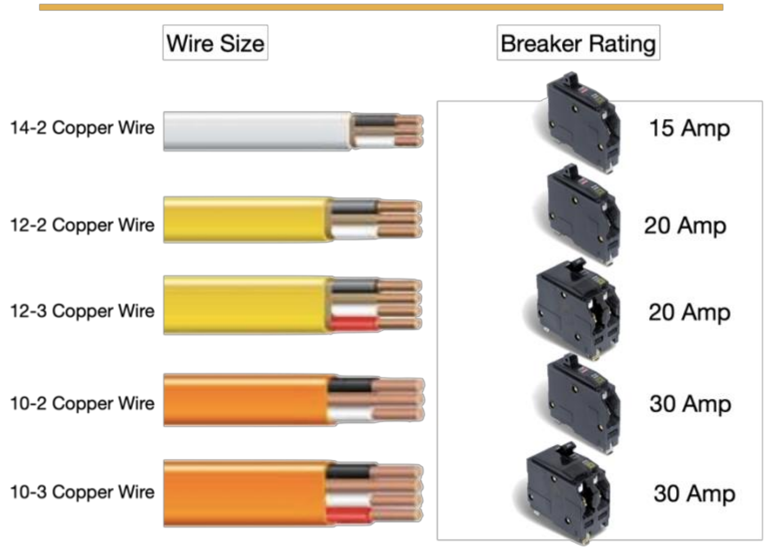
Watts = Current x Voltage

$$W = I \times V$$

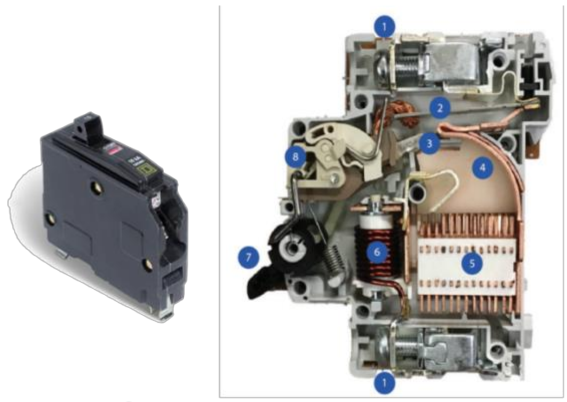
$$W = I^2 \times R$$

$$W = \frac{V^2}{R}$$

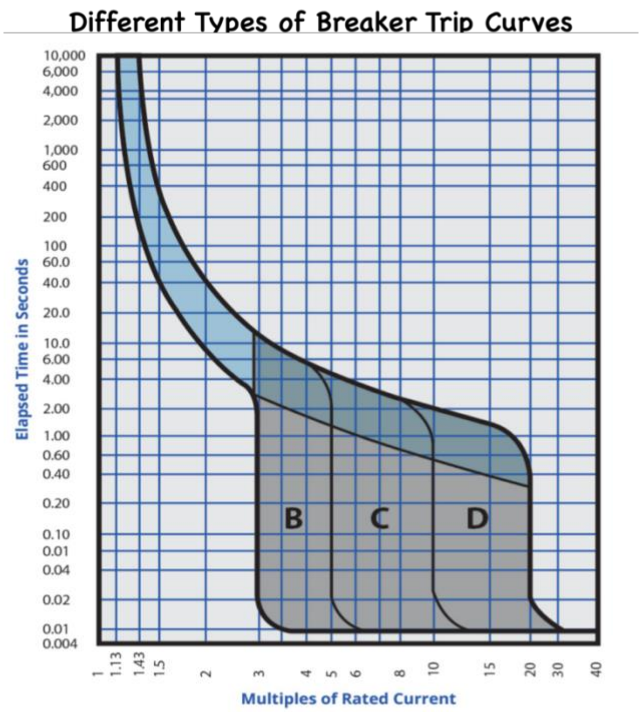
American Wire Gauge (AWG)	
AWG	Current (amps)
2	95
3	85
4	70
6	55
8	40
10	30
12	20
14	15
16	13
18	10



Rompedores de circuito



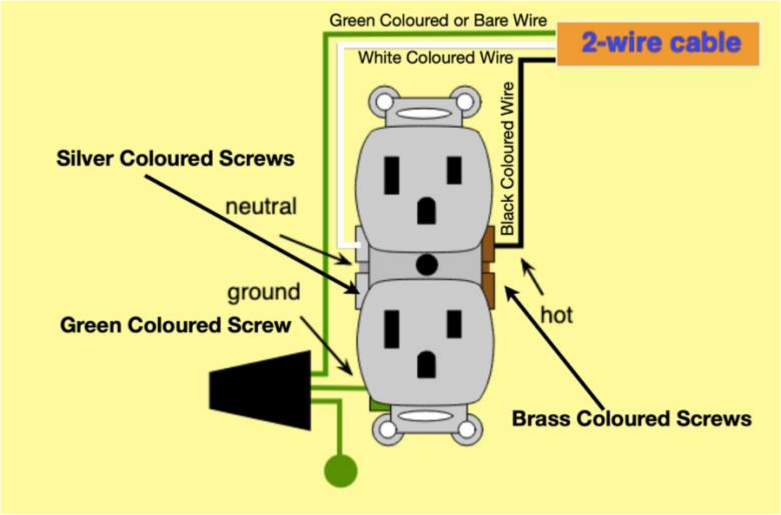
1. Terminal for line/load power.
2. Bi-metallic strip. Bends with heat (current).
3. Contacts. Current flows through when closed.
4. Arc Chamber.
5. Arc divider/extinguisher.
6. Coil/Solenoid. Response to high overcurrents
7. Actuator lever. Manually trips or resets.
8. Actuator mechanism. Forces contacts together or apart.

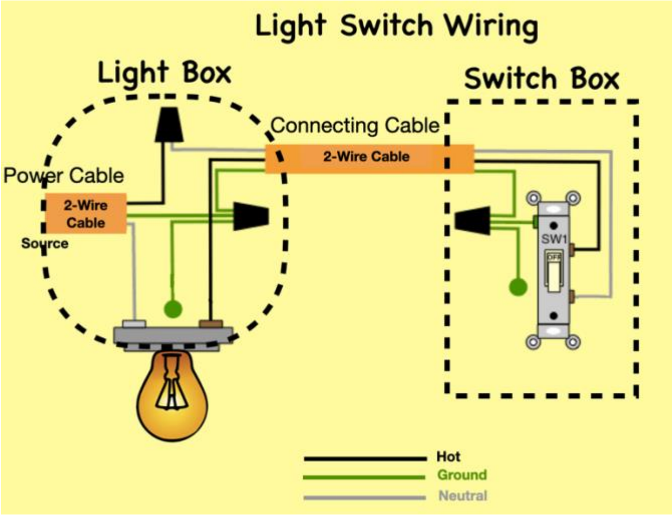


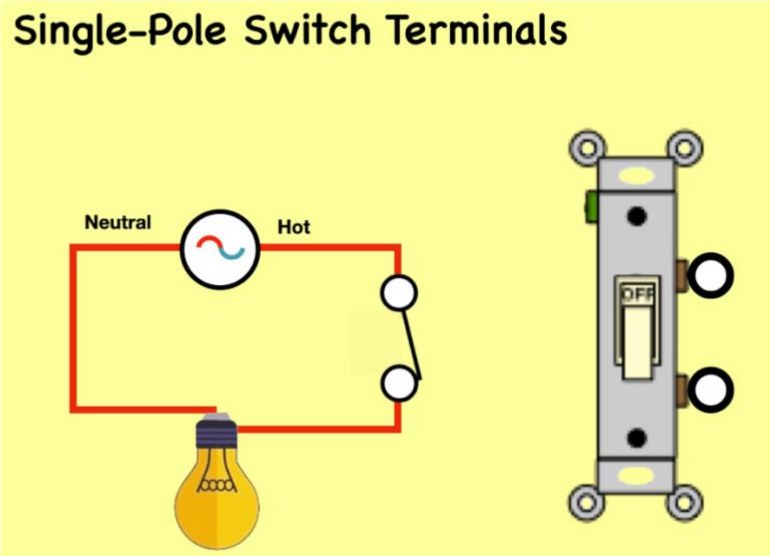
THHN - Thermoplastic High Heat-resistant Nylon-coated wire

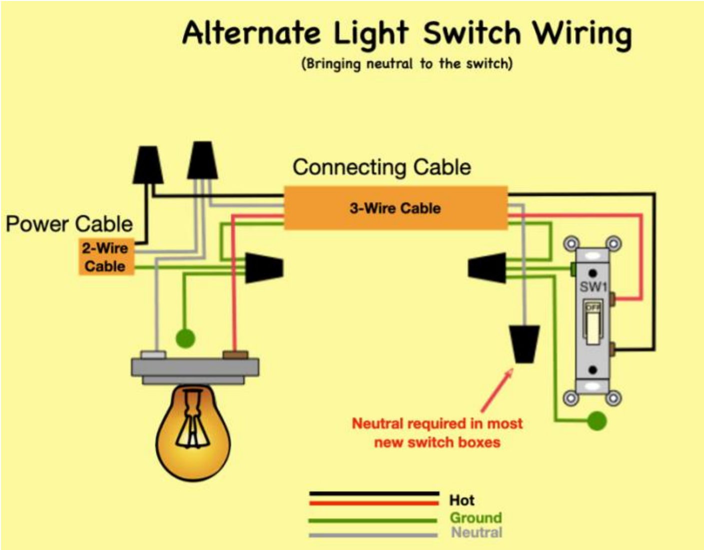
THWN - same as THHN, "W" water- resistance

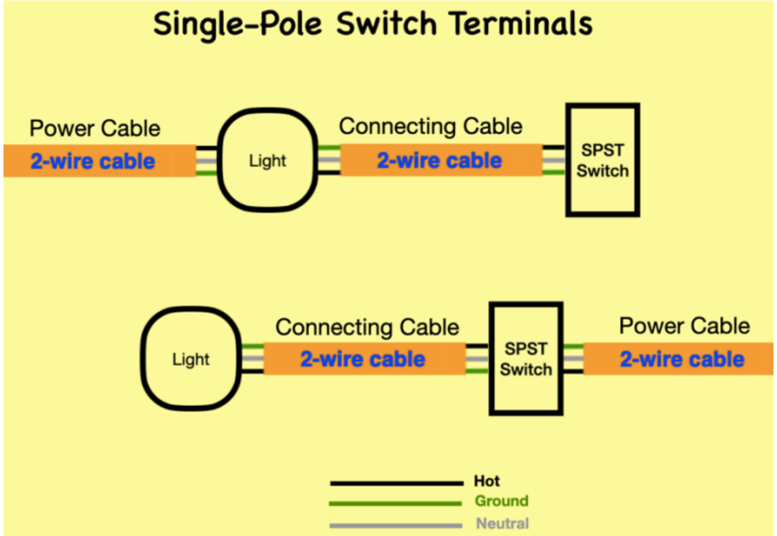
Romex - Thermoplastic-Sheathed Cable (TPS) NM-D, or B.

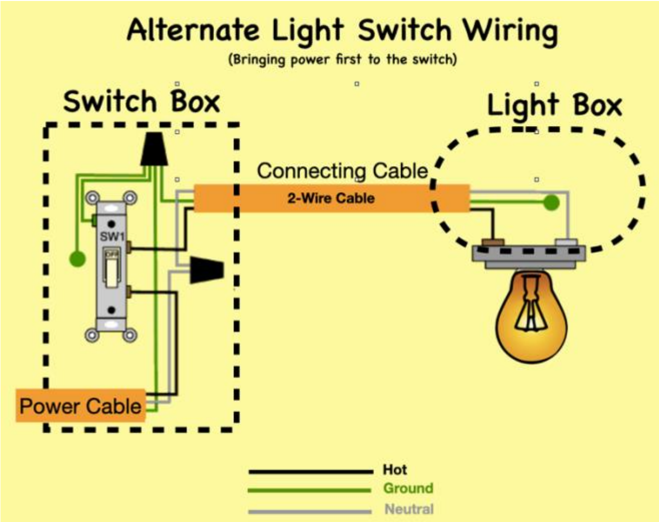

Green Coloured or Bare Wire
2-wire cable
White Coloured Wire
Black Coloured Wire
Silver Coloured Screws
neutral
ground
Green Coloured Screw
hot
Brass Coloured Screws

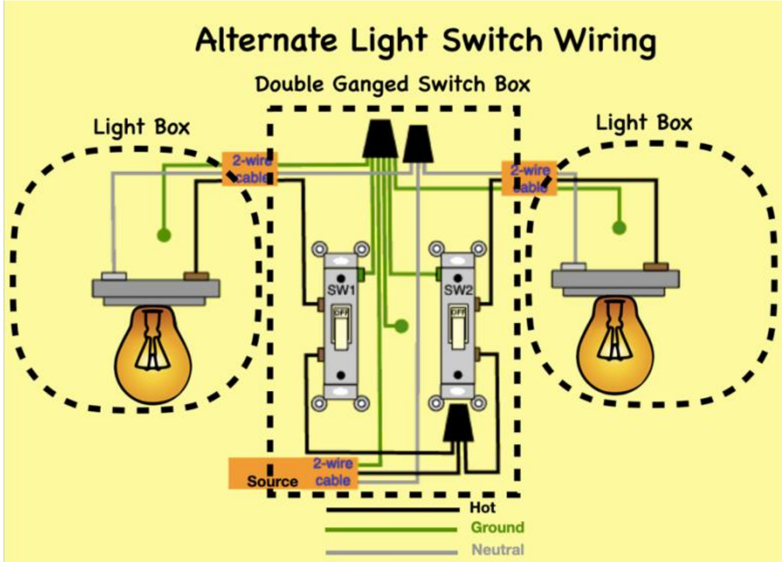

Light Switch Wiring
Light Box
Switch Box
Connecting Cable
2-Wire Cable
Power Cable
2-Wire Cable
Source
SW1
OFF
Hot
Ground
Neutral

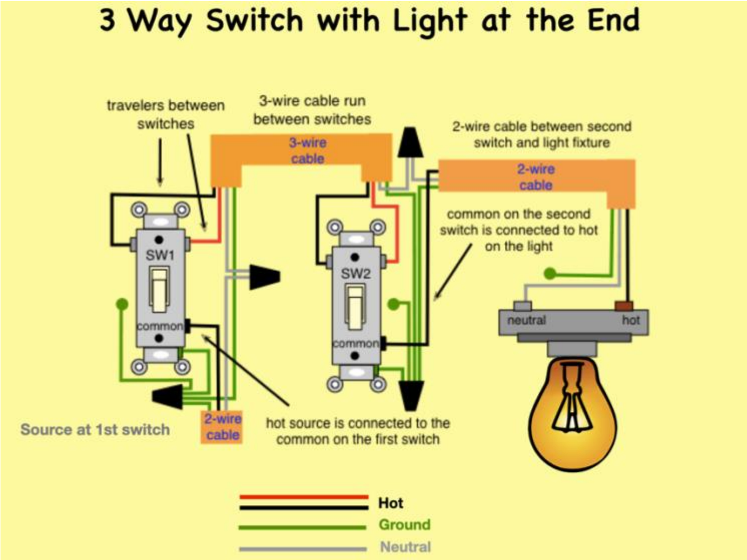

Single-Pole Switch Terminals
Neutral
Hot
OFF

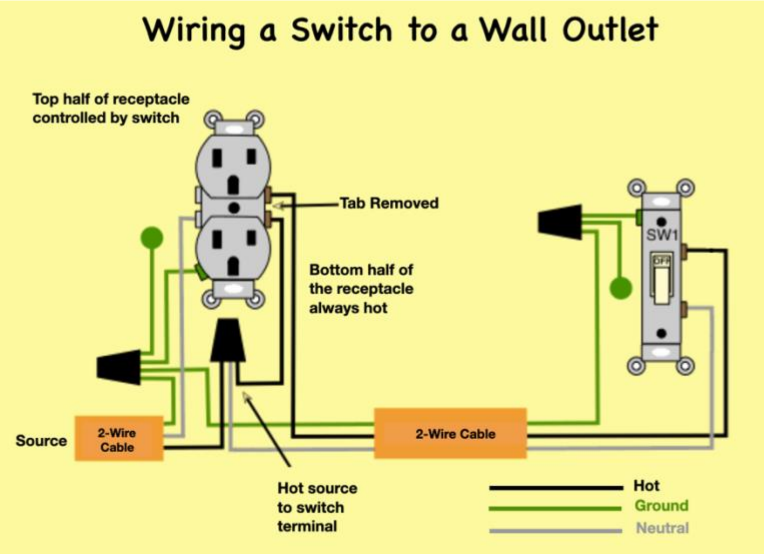

Alternate Light Switch Wiring
(Bringing neutral to the switch)
Connecting Cable
3-Wire Cable
Power Cable
2-Wire Cable
SW1
OFF
Neutral required in most new switch boxes
Hot
Ground
Neutral

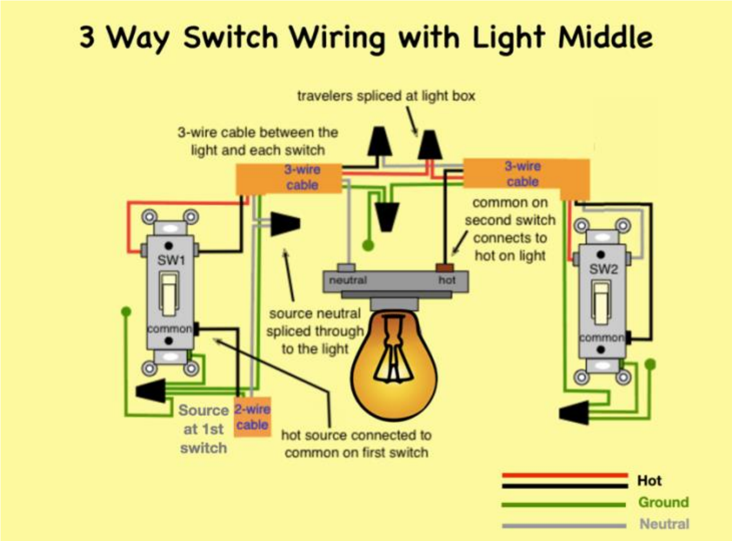

Single-Pole Switch Terminals
Power Cable
2-wire cable
Light
Connecting Cable
2-wire cable
SPST Switch
Light
Connecting Cable
2-wire cable
SPST Switch
Power Cable
2-wire cable
Hot
Ground
Neutral

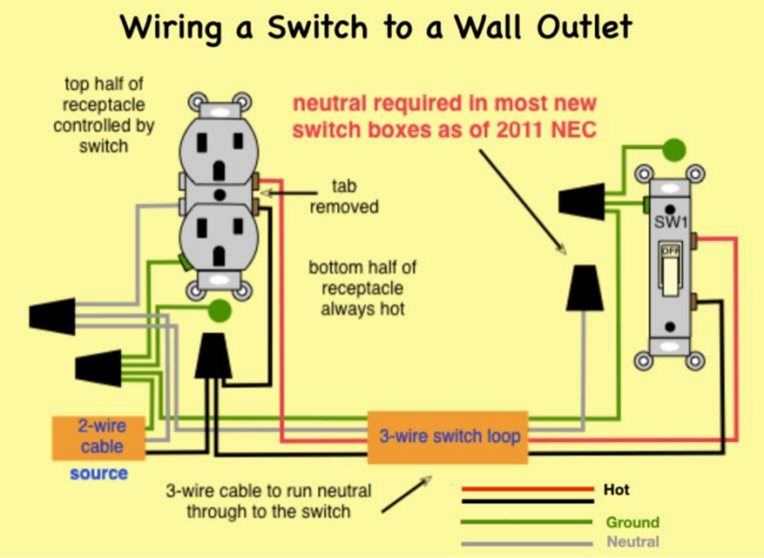

Alternate Light Switch Wiring
(Bringing power first to the switch)
Switch Box
Light Box
Connecting Cable
2-Wire Cable
SW1
OFF
Power Cable
Hot
Ground
Neutral

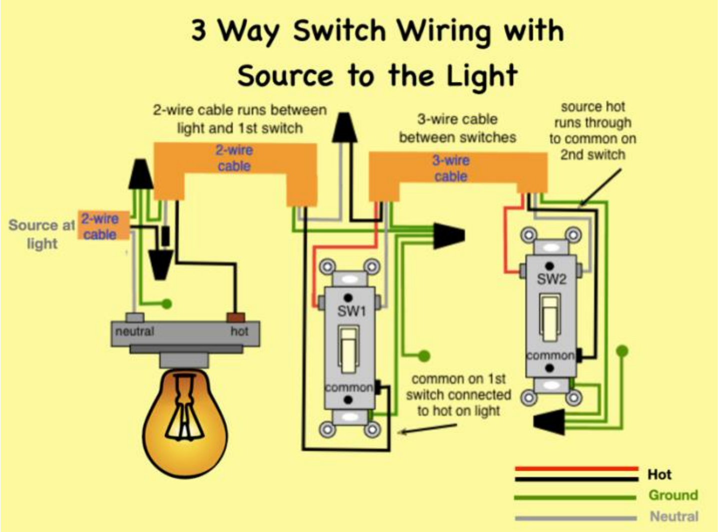

Alternate Light Switch Wiring
Double Ganged Switch Box
Light Box
Light Box
2-wire cable
2-wire cable
SW1
SW2
Source
2-wire cable
Hot
Ground
Neutral

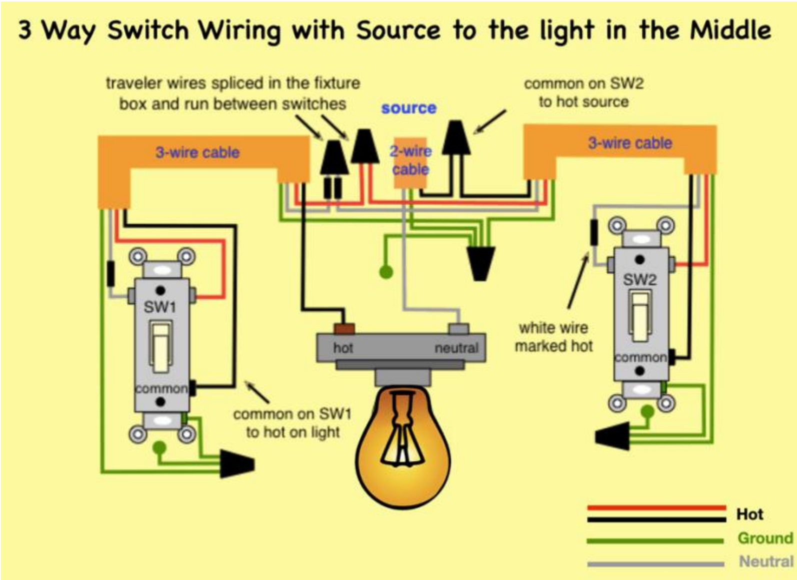

3 Way Switch with Light at the End
travelers between switches
3-wire cable run between switches
3-wire cable
2-wire cable between second switch and light fixture
2-wire cable
common on the second switch is connected to hot on the light
SW1
SW2
common
common
neutral
hot
Source at 1st switch
2-wire cable
hot source is connected to the common on the first switch
Hot
Ground
Neutral

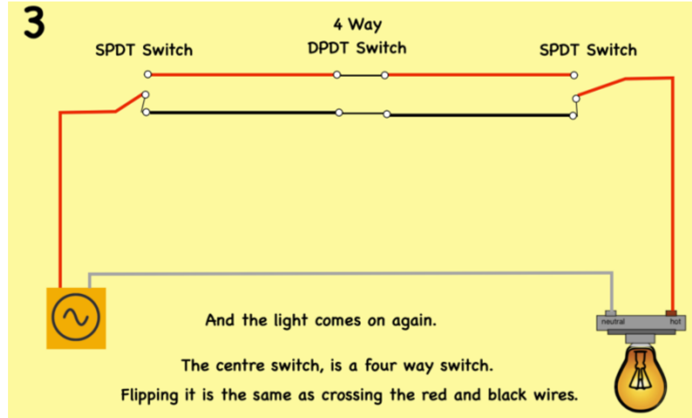

Wiring a Switch to a Wall Outlet
Top half of receptacle controlled by switch
Tab Removed
Bottom half of the receptacle always hot
SW1
Source
2-Wire Cable
2-Wire Cable
Hot source to switch terminal
Hot
Ground
Neutral

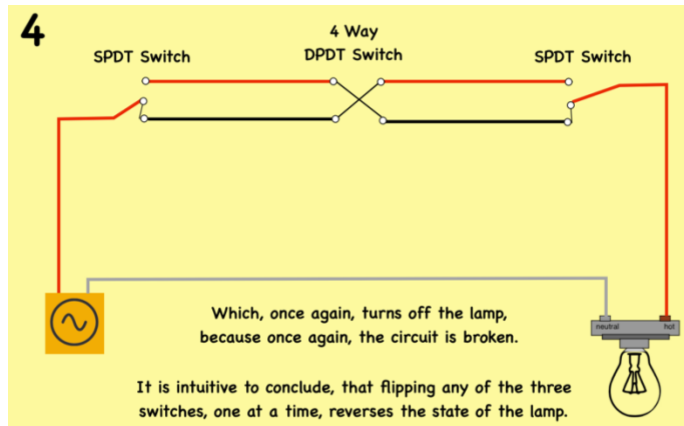

3 Way Switch Wiring with Light Middle
travelers spliced at light box
3-wire cable between the light and each switch
3-wire cable
3-wire cable
common on second switch connects to hot on light
SW1
SW2
neutral
hot
common
common
source neutral spliced through to the light
Source at 1st switch
2-wire cable
hot source connected to common on first switch
Hot
Ground
Neutral


Wiring a Switch to a Wall Outlet
top half of receptacle controlled by switch
neutral required in most new switch boxes as of 2011 NEC
tab removed
bottom half of receptacle always hot
SW1
2-wire cable
source
3-wire switch loop
3-wire cable to run neutral through to the switch
Hot
Ground
Neutral

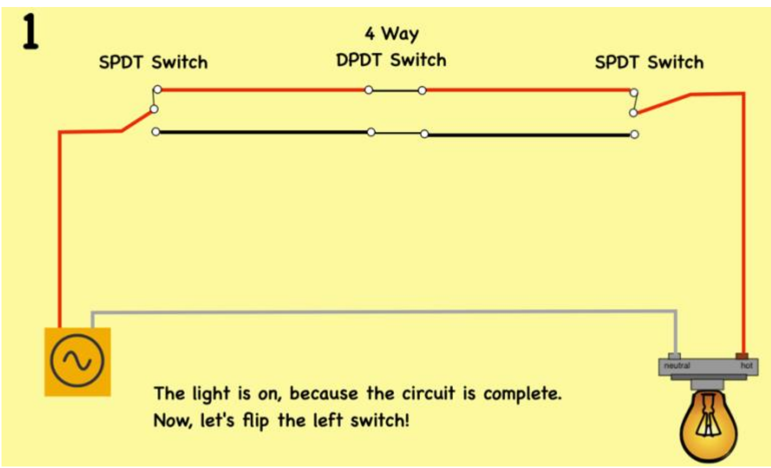

3 Way Switch Wiring with Source to the Light
2-wire cable runs between light and 1st switch
2-wire cable
3-wire cable between switches
3-wire cable
source hot runs through to common on 2nd switch
Source at light
2-wire cable
neutral
hot
SW1
SW2
common
common
common on 1st switch connected to hot on light
Hot
Ground
Neutral

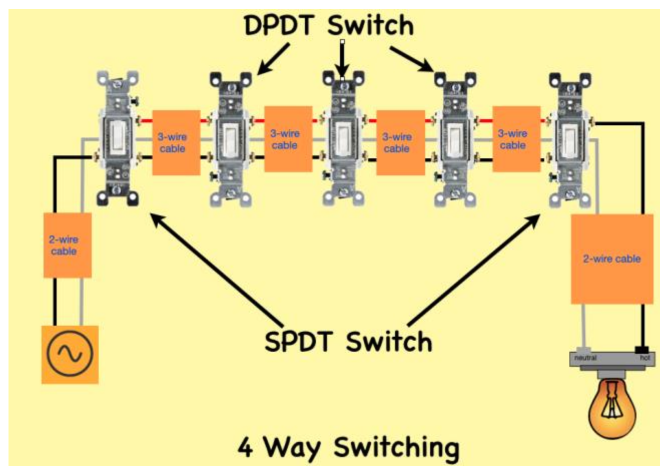


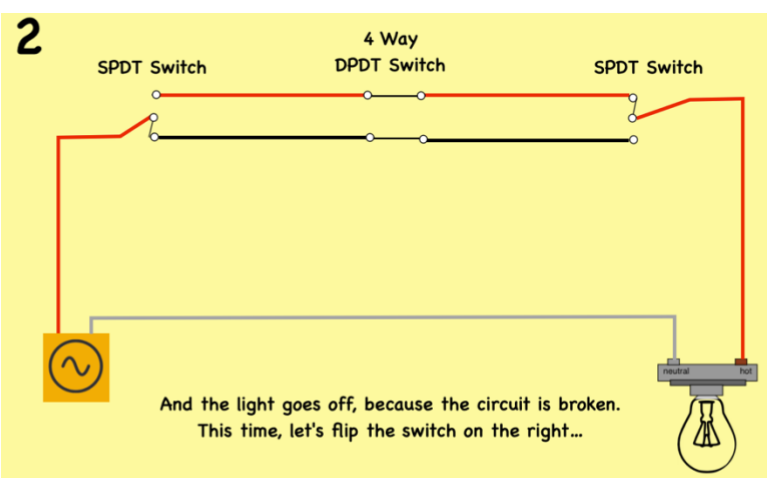


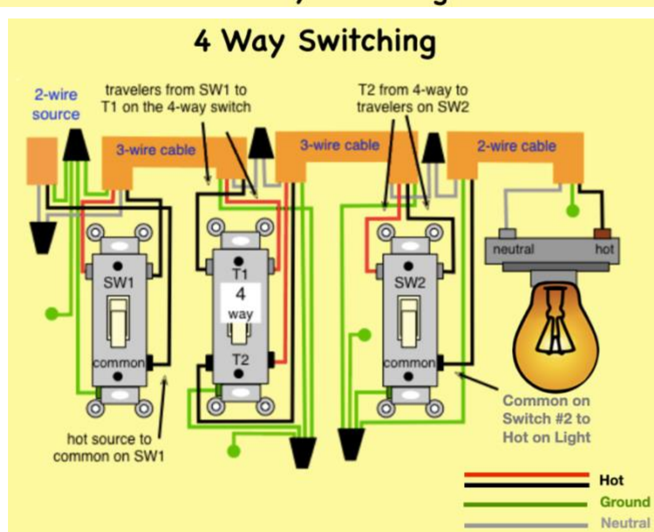


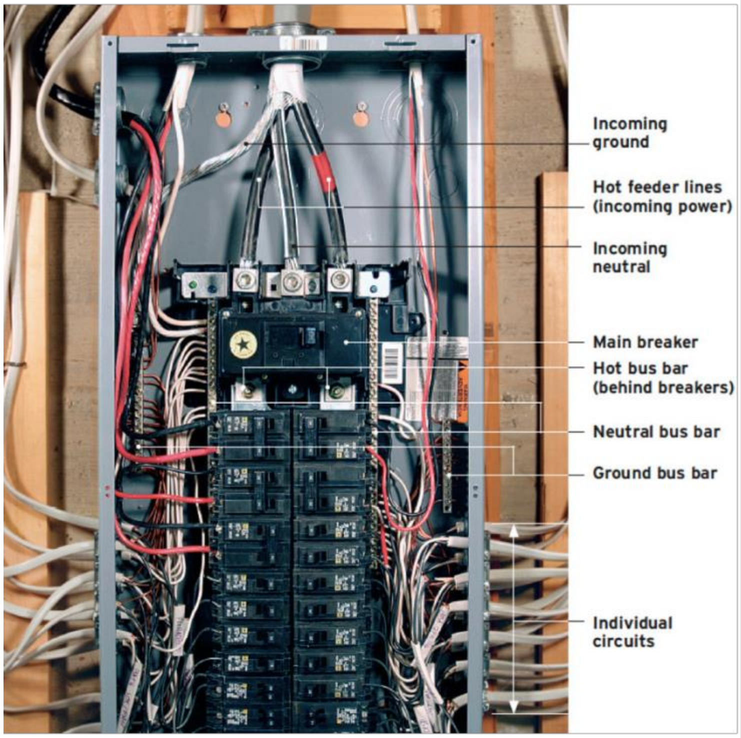
Las siguientes cuatro diapositivas demuestran esquemáticamente cómo se conecta y funciona un interruptor de cuatro vías.

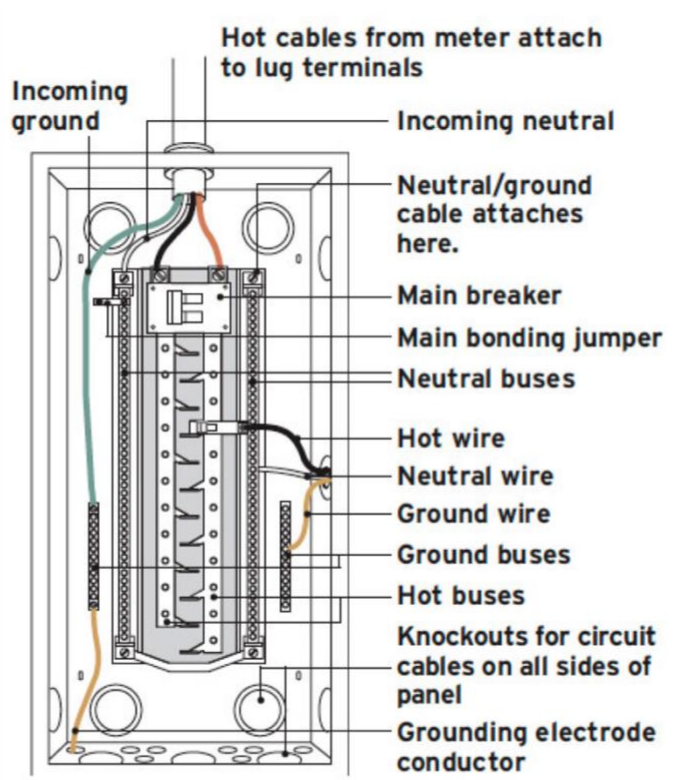


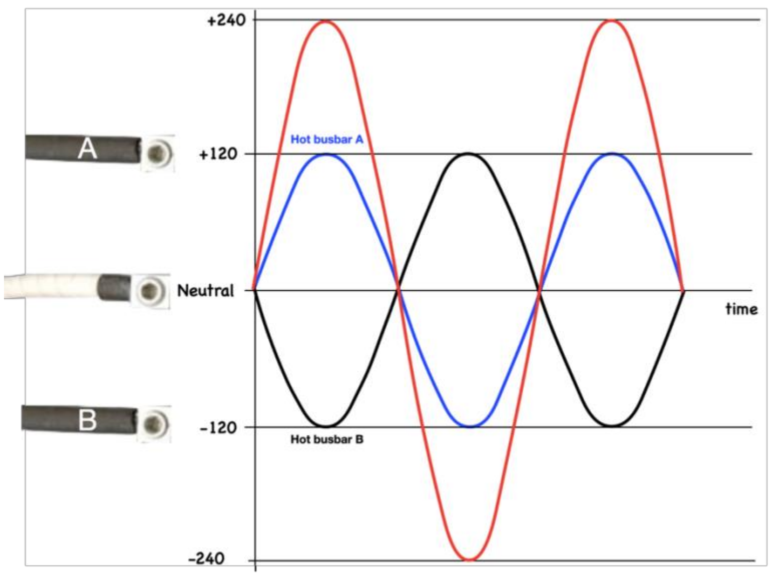








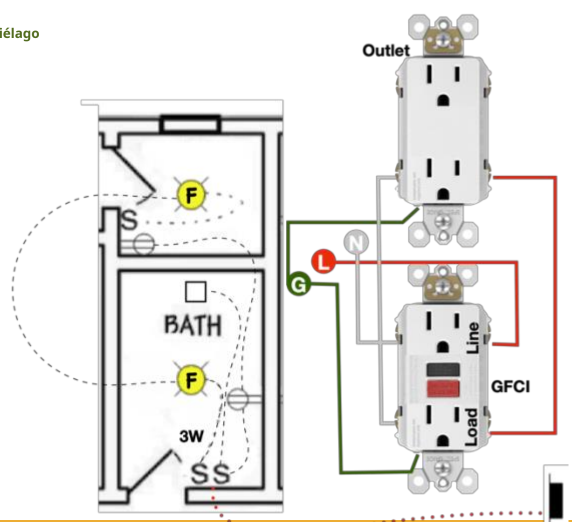


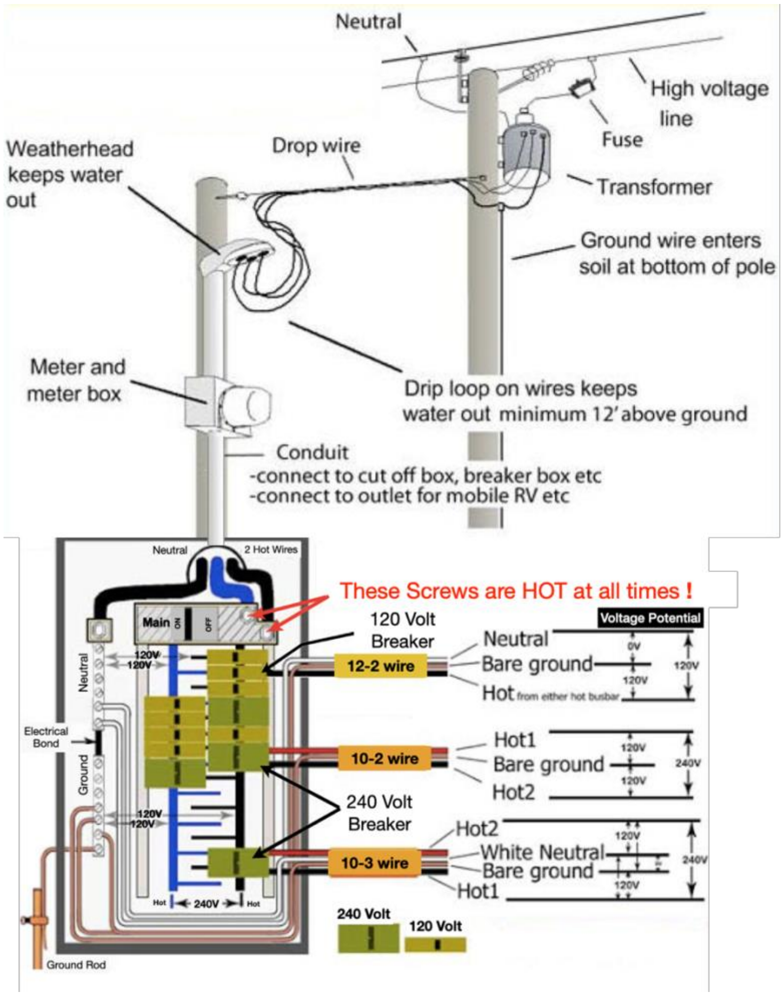


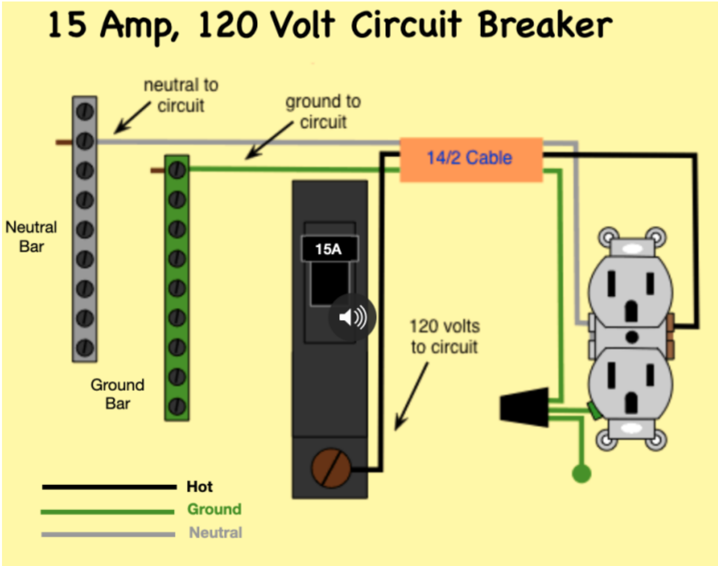
Símbolos estándar del diagrama de cableado doméstico

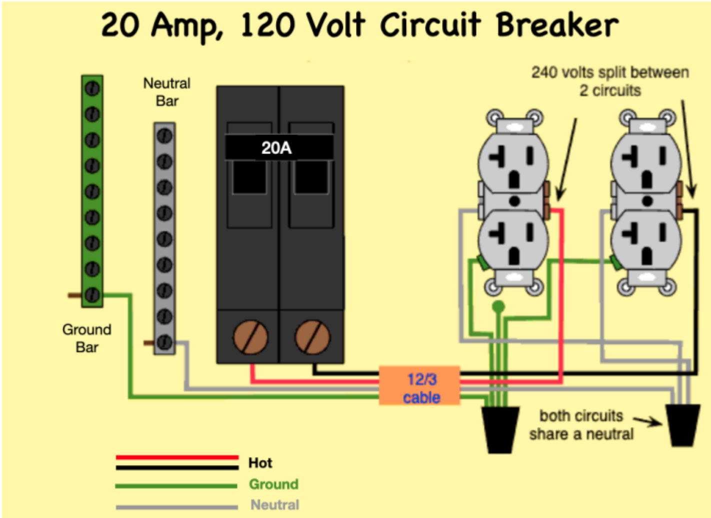
	Electrical switchbox	S	Single Pole Switch
S_3	Three-Way Switch		SinglePlex Receptacle
	Duplex Receptacle	WP	Duplex Receptacle WP= Waterproof
GFCI	GFCI Duplex Receptacle	*	Isolated Ground Receptacle
	Switched Receptacle		FourPlex Four Gang Receptacle
	240-Volt Receptacle	PC	Ceiling Mounted Light Fixture PC= Pullchain
	Wall-Mounted Light Fixture	R	Recessed Light Fixture
WP	Weatherproof Light Fixture		Fluorescent Light Fixture
CF	Ceiling Fan		Combination Light & Fan
VF	Power Vent Fan	2	Electric Motor Number=HP
SD	Smoke Detector		Circuit Breaker
	Telephone Jack	T	Doorbell Transformer
	Doorbell Pushbutton		Ground

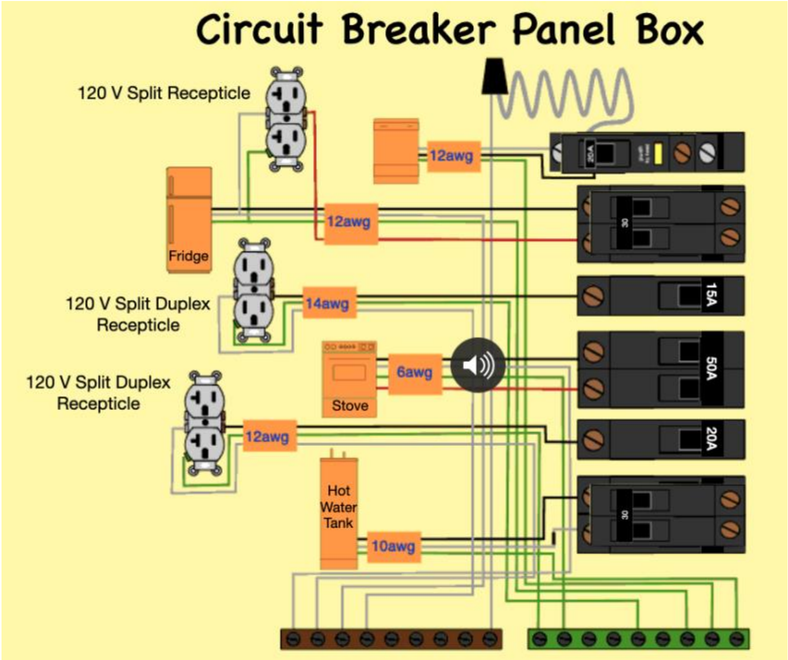
Murciélago

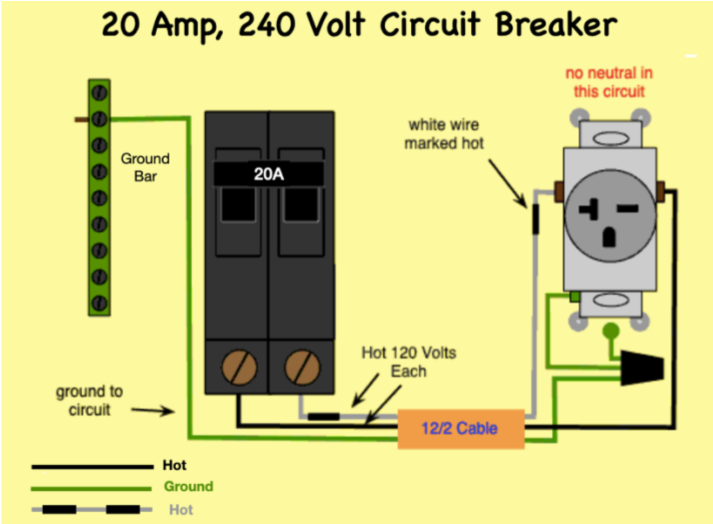


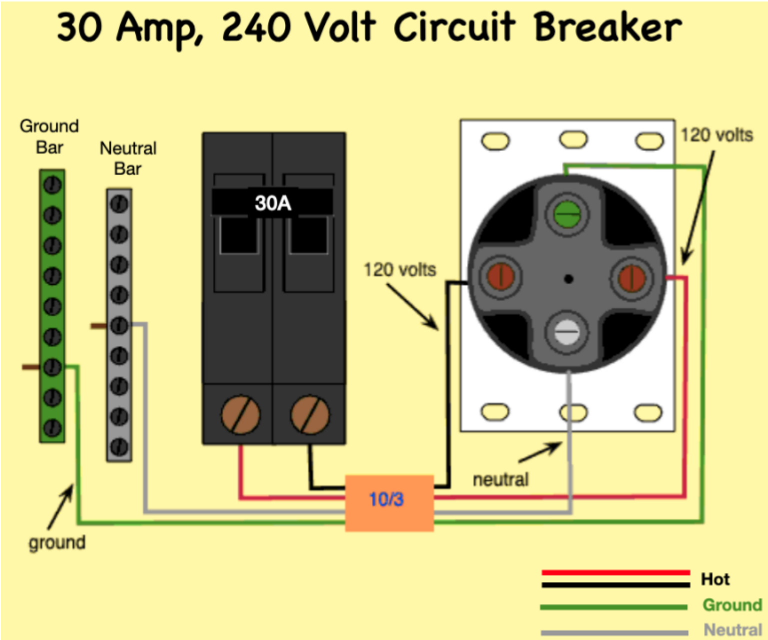

Neutral
High voltage line
Fuse
Weatherhead keeps water out
Drop wire
Transformer
Ground wire enters soil at bottom of pole
Meter and meter box
Drip loop on wires keeps water out minimum 12' above ground
Conduit
-connect to cut off box, breaker box etc
-connect to outlet for mobile RV etc
Neutral
2 Hot Wires
These Screws are HOT at all times !
Main
120 Volt Breaker
Voltage Potential
Neutral
Bare ground
Hot from either hot busbar
12-2 wire
Electrical Bond
Hot1
Bare ground
Hot2
10-2 wire
240 Volt Breaker
Hot2
White Neutral
Bare ground
Hot1
10-3 wire
240V
Ground Rod
240 Volt
120 Volt

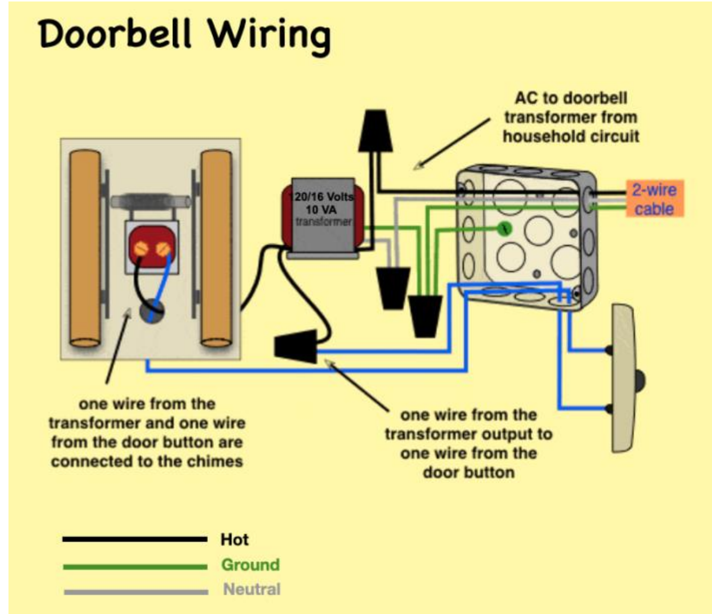

15 Amp, 120 Volt Circuit Breaker
neutral to circuit
ground to circuit
14/2 Cable
Neutral Bar
15A
120 volts to circuit
Ground Bar
Hot
Ground
Neutral

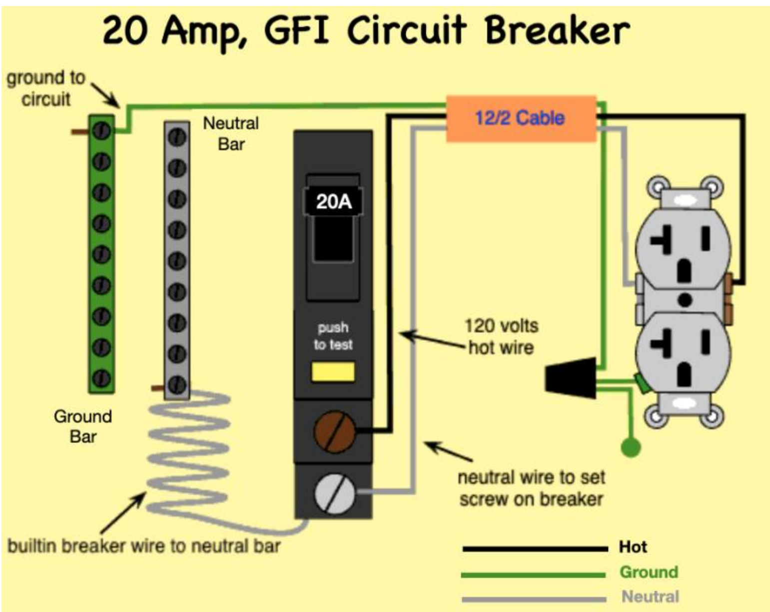

20 Amp, 120 Volt Circuit Breaker
Neutral Bar
240 volts split between 2 circuits
20A
Ground Bar
12/3 cable
both circuits share a neutral
Hot
Ground
Neutral

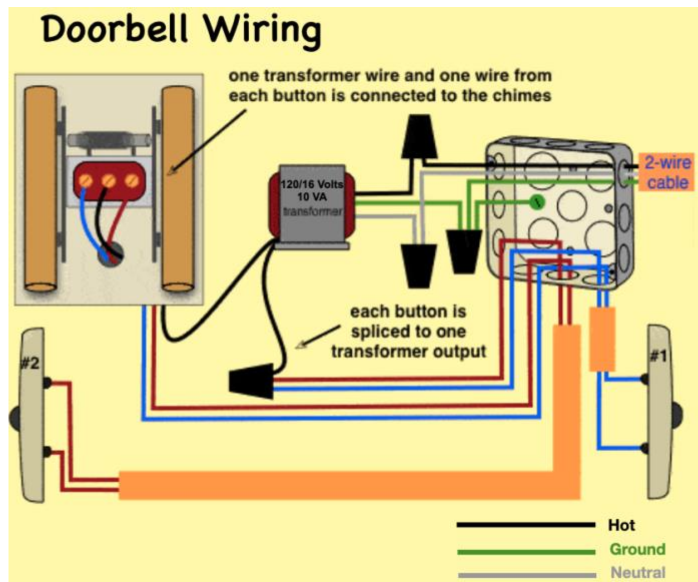

Circuit Breaker Panel Box
120 V Split Recepticle
12awg
Fridge
12awg
120 V Split Duplex Recepticle
14awg
15A
6awg
Stove
50A
120 V Split Duplex Recepticle
12awg
20A
Hot Water Tank
10awg


20 Amp, 240 Volt Circuit Breaker
no neutral in this circuit
white wire marked hot
Ground Bar
20A
Hot 120 Volts Each
ground to circuit
12/2 Cable
Hot
Ground
Hot

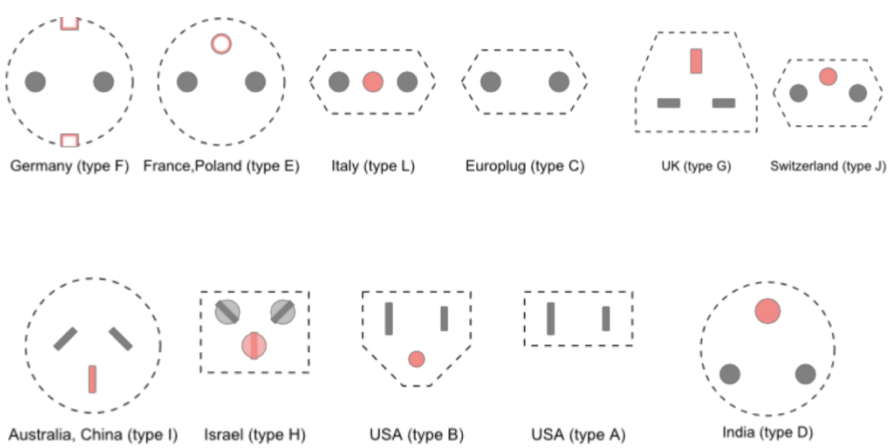








Tipos de puntos de venta en todo el mundo



Check the Label on the Wire Nuts Packaging

Model	AWG wire sizes fit for	Dimensions (Millimet)	Color	Material
SP1	MIN 2X#22 MAX 2X#16	0.59x0.34 inch	Grey	Screw terminals: copper Insulated screw tube: nylon
SP2	MIN 2X#22 MAX 3X#16	0.69x0.4 inch	Blue	
SP3	MIN 1X#18+ 1X#20 MAX 4X#16 MAX 1X#20	0.87x0.49 inch	Orange	
SP4	MIN 2X#18 MAX 4X#16 MAX 1X#18	0.96x0.54 inch	Yellow	
SP5	MIN 2X#14 MAX 4X#10 MIAX 2X#12	1.05x0.63 inch	Red	