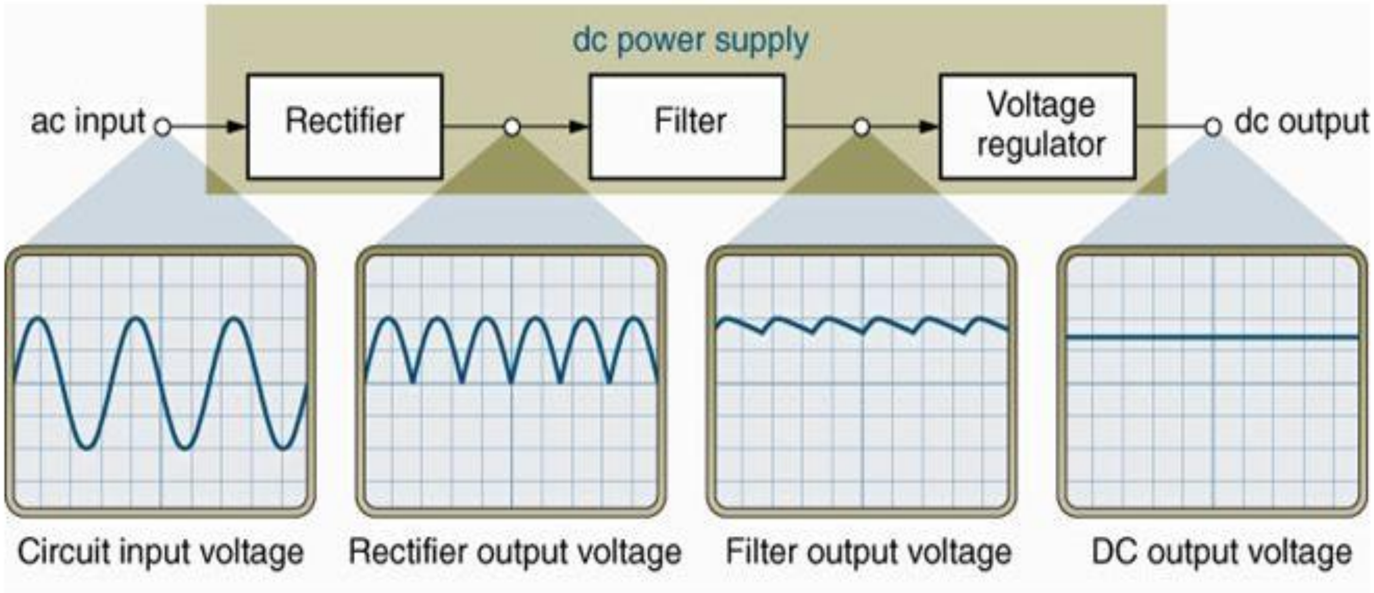
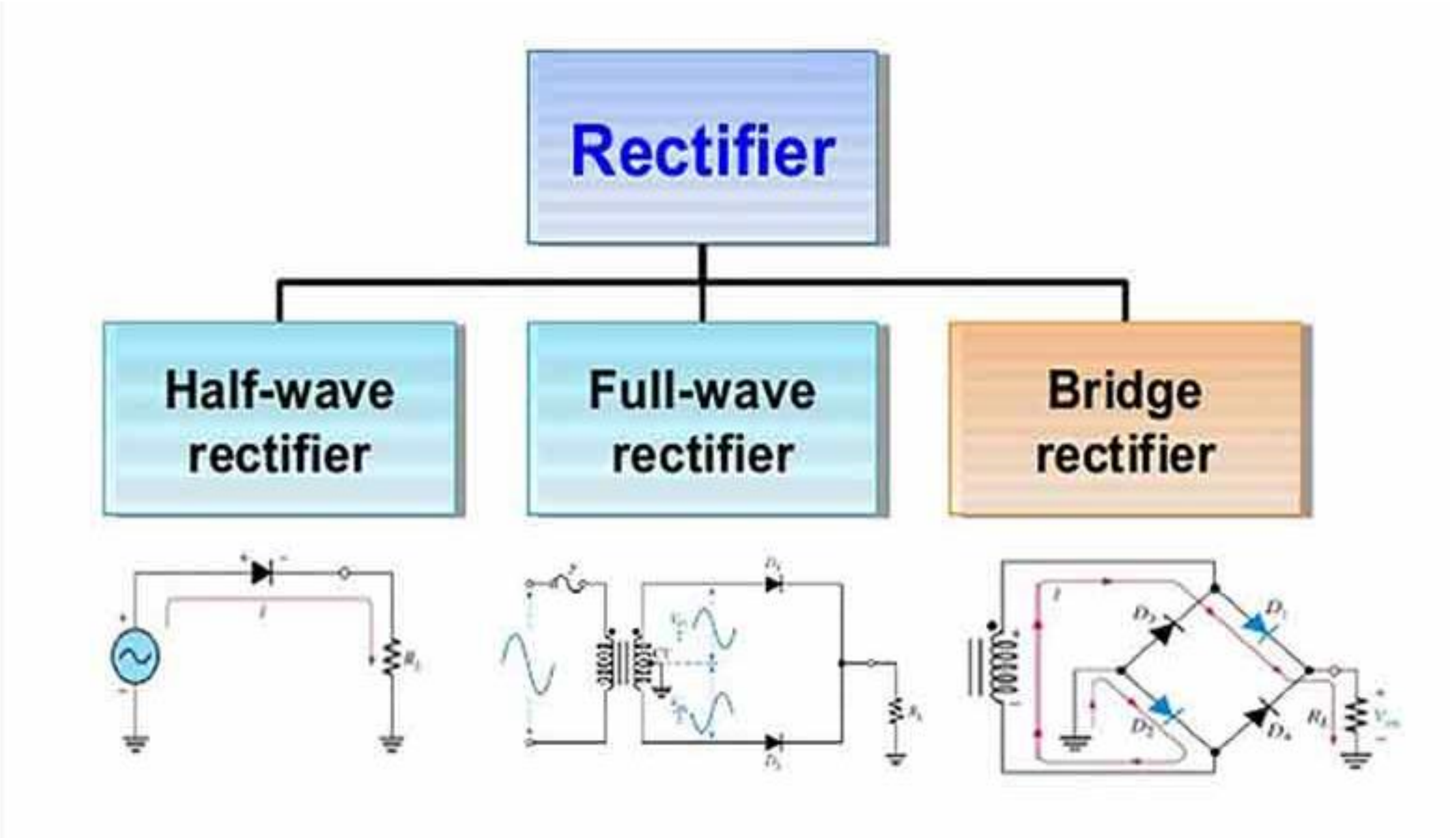
AC to DC Current

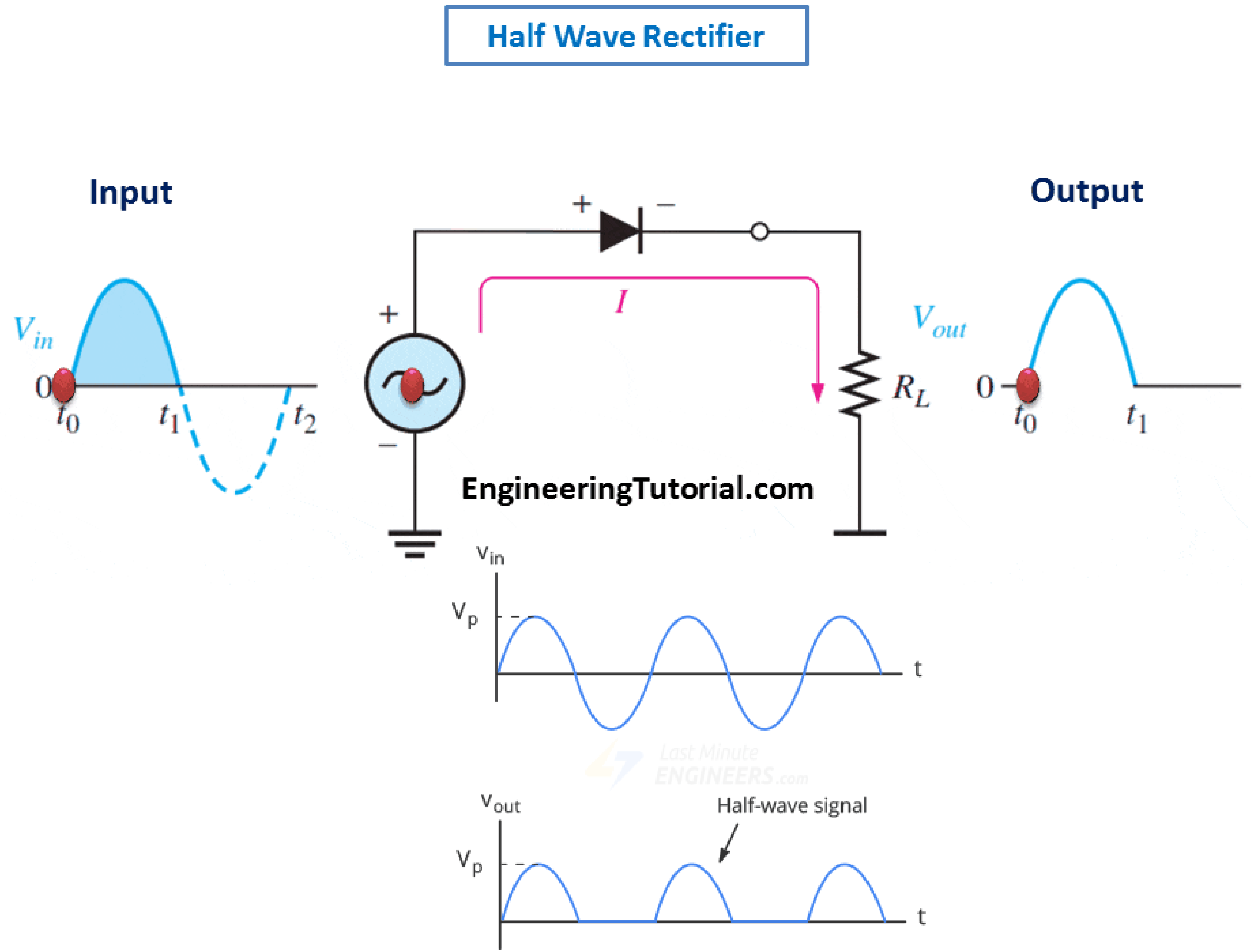
A group of circuits used to convert ac to dc.

- Rectifier – Converts ac to pulsating dc.
- Filter – Reduces variations in the rectifier output.
- Voltage regulator – Maintains a constant dc output voltage.



Types of Rectifier



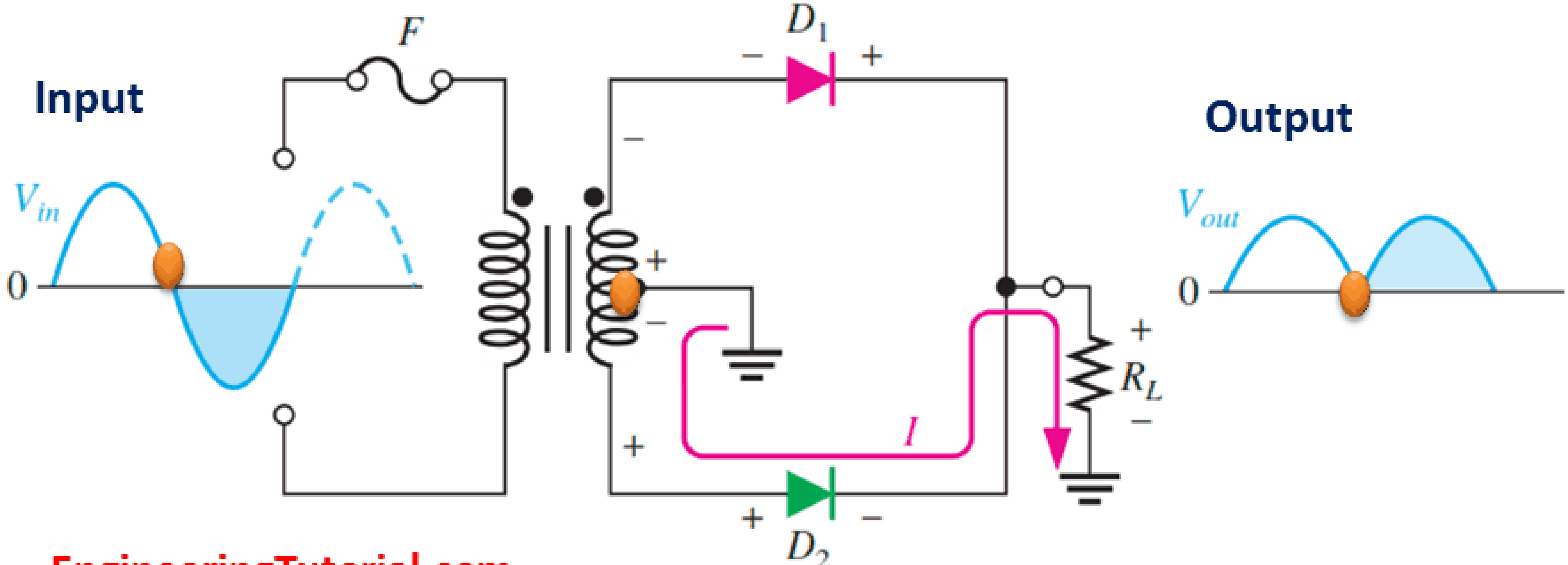


Half Wave Rectifier
Input
Output
V_{in}
0
t_0
t_1
t_2
+
−
I
V_{out}
R_L
EngineeringTutorial.com
v_{in}
V_p
t
Last Minute ENGINEERS.com
v_{out}
Half-wave signal

Center Tapped Full Wave Rectifier

During Negative Half Cycle

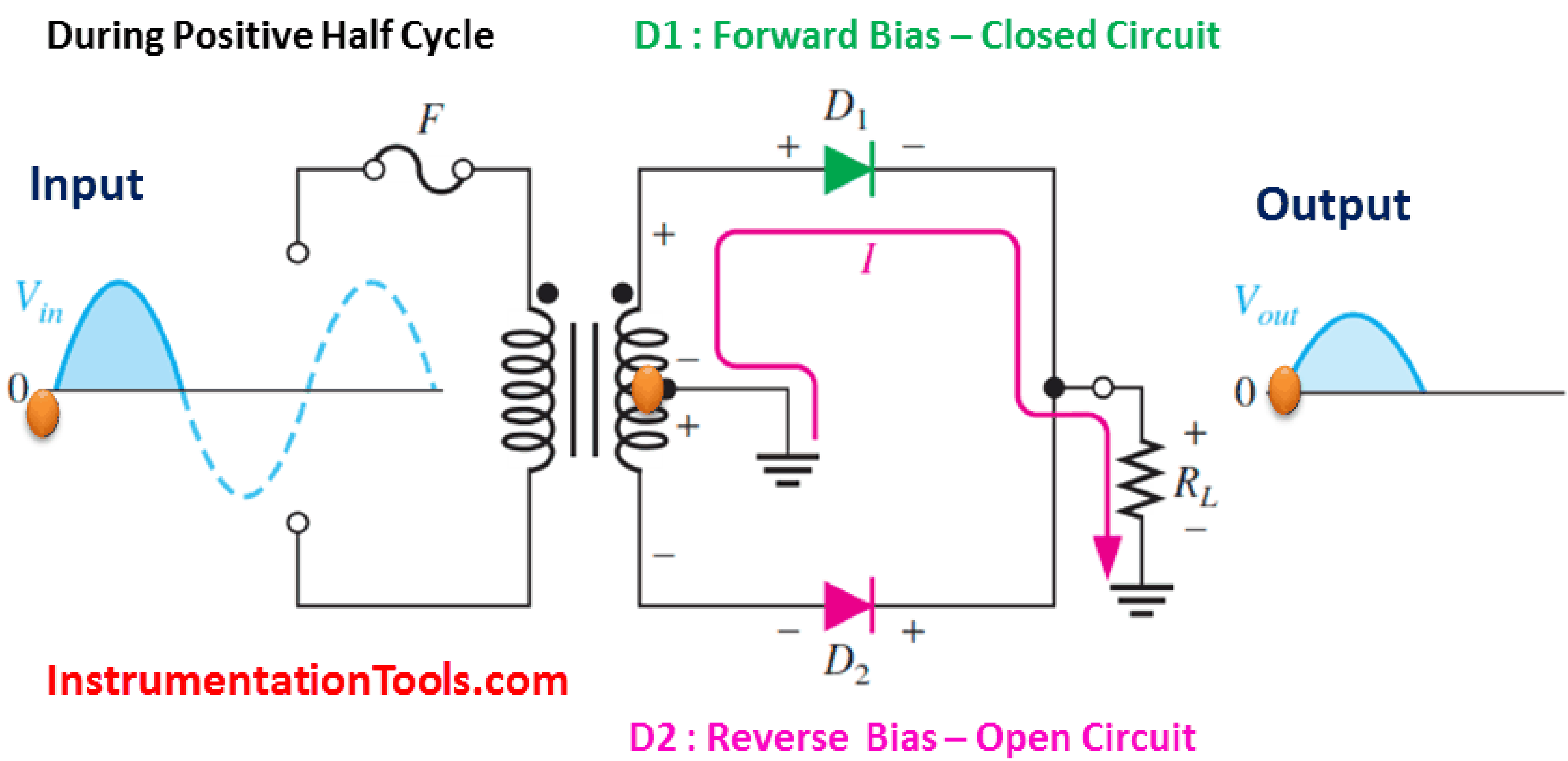
D1 : Reverse Bias – Open Circuit

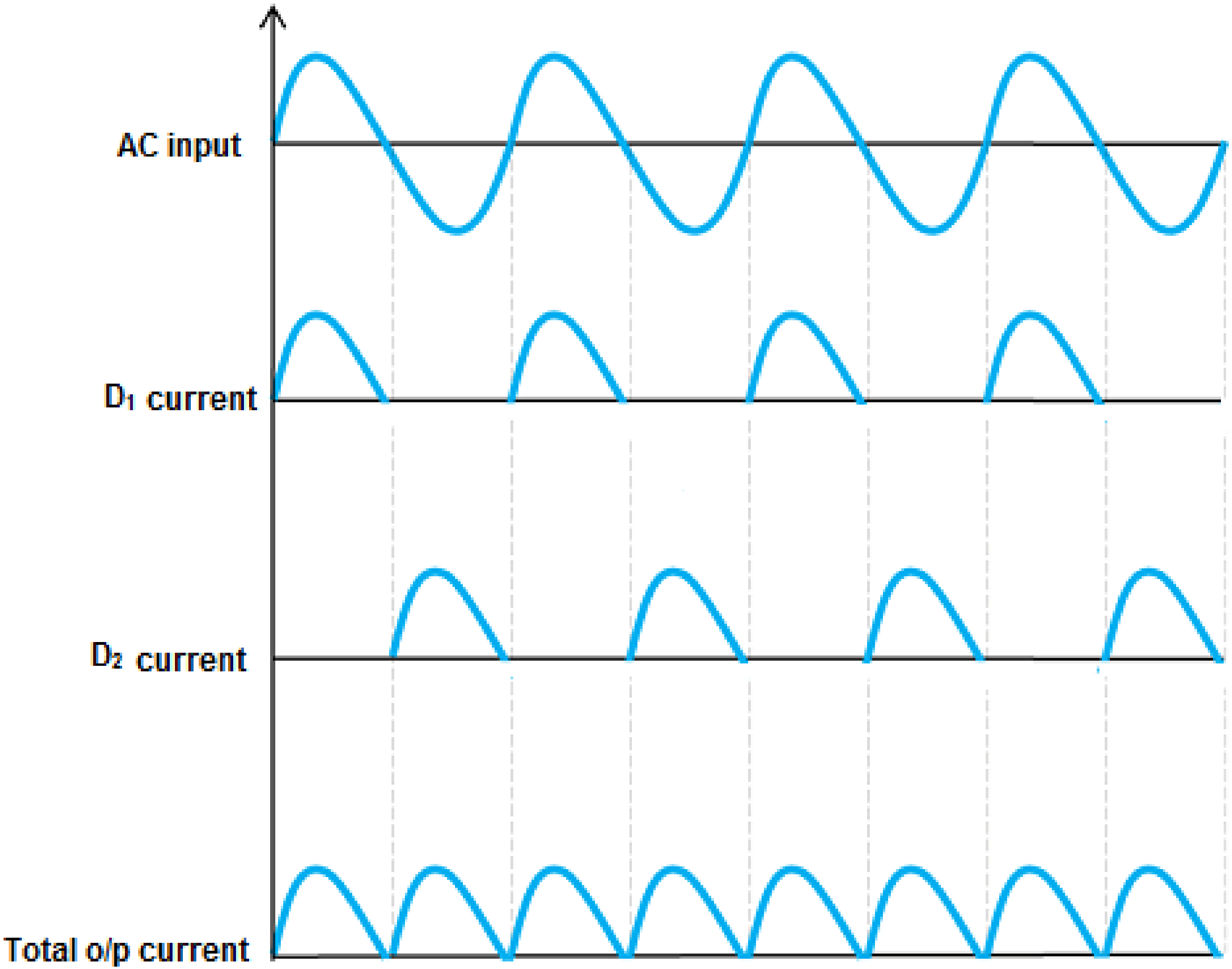


EngineeringTutorial.com

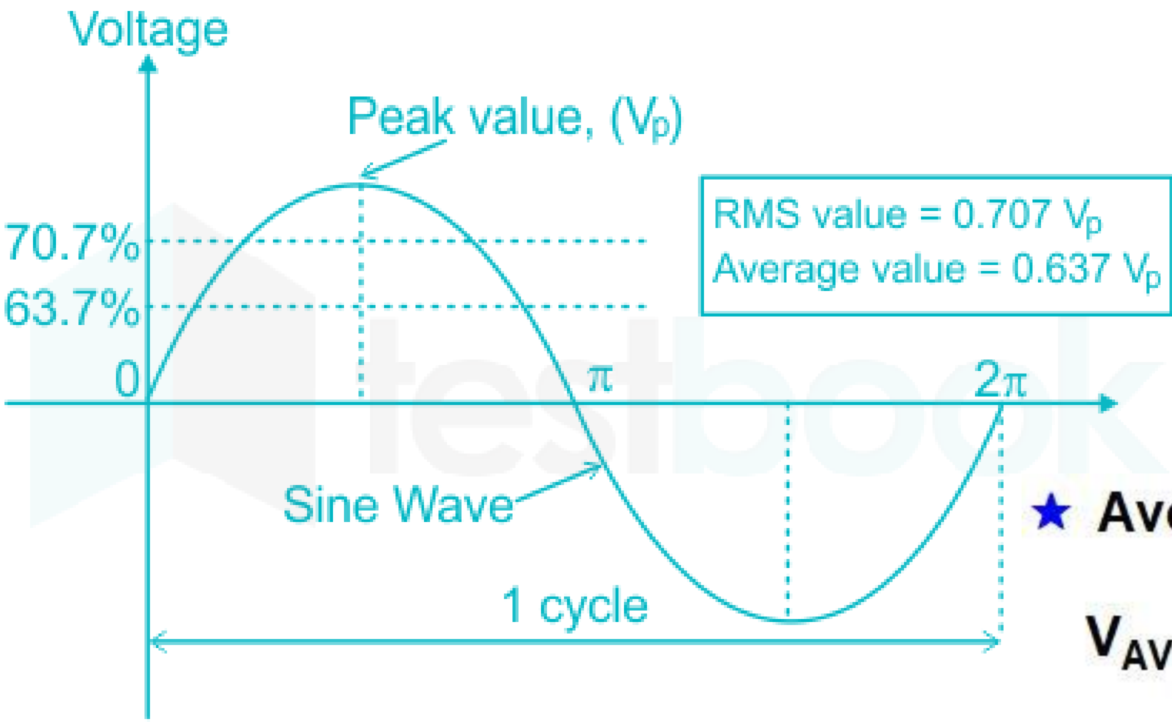
D2 : Forward Bias – Closed Circuit

Center Tapped Full Wave Rectifier




AC input
D1 current
D2 current
Total o/p current

RMS and Average Value



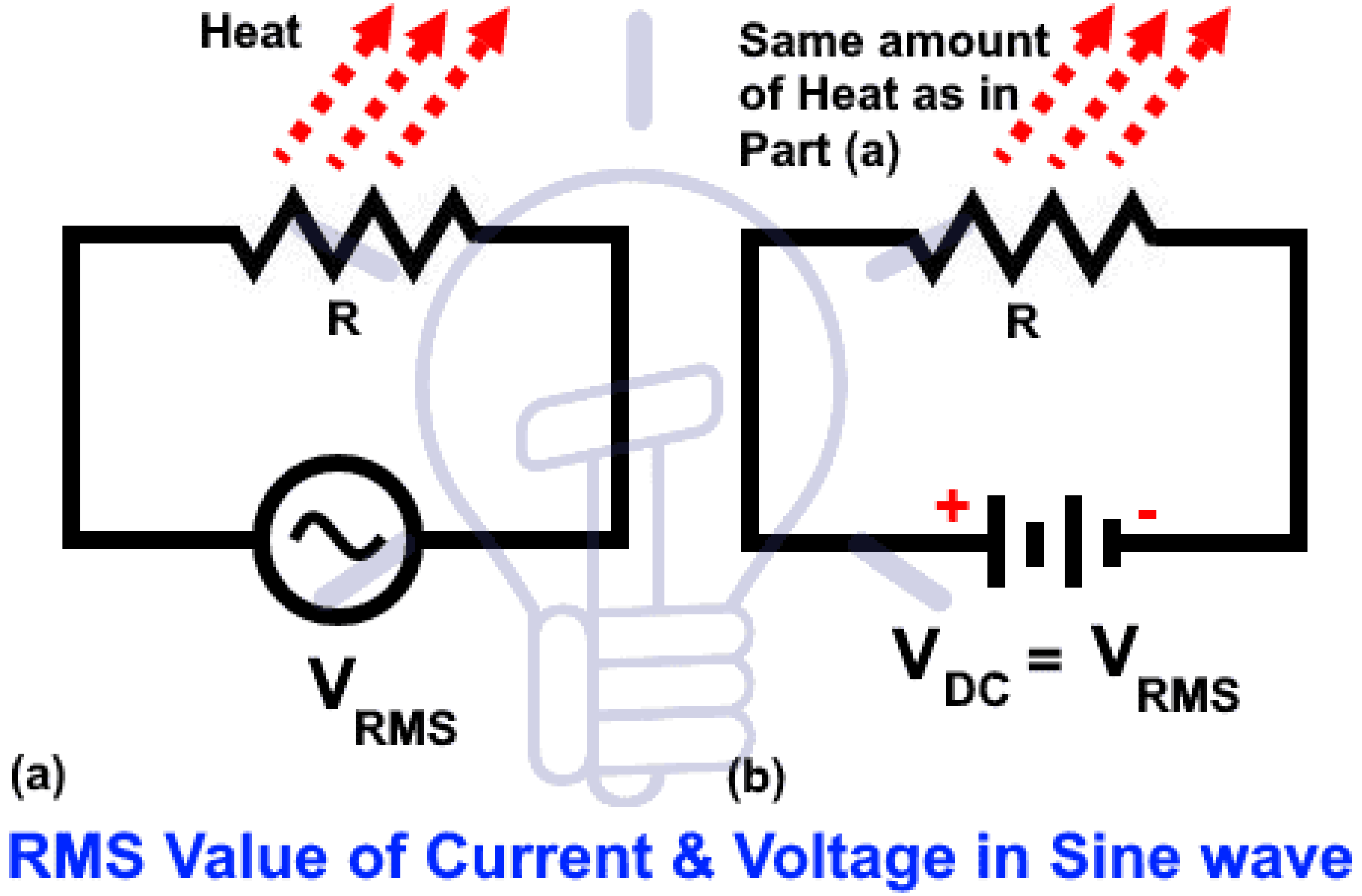
★ **Average Voltage Value**

$$V_{AV} = \frac{2V_P}{\pi} = 0.637 \times V_P$$

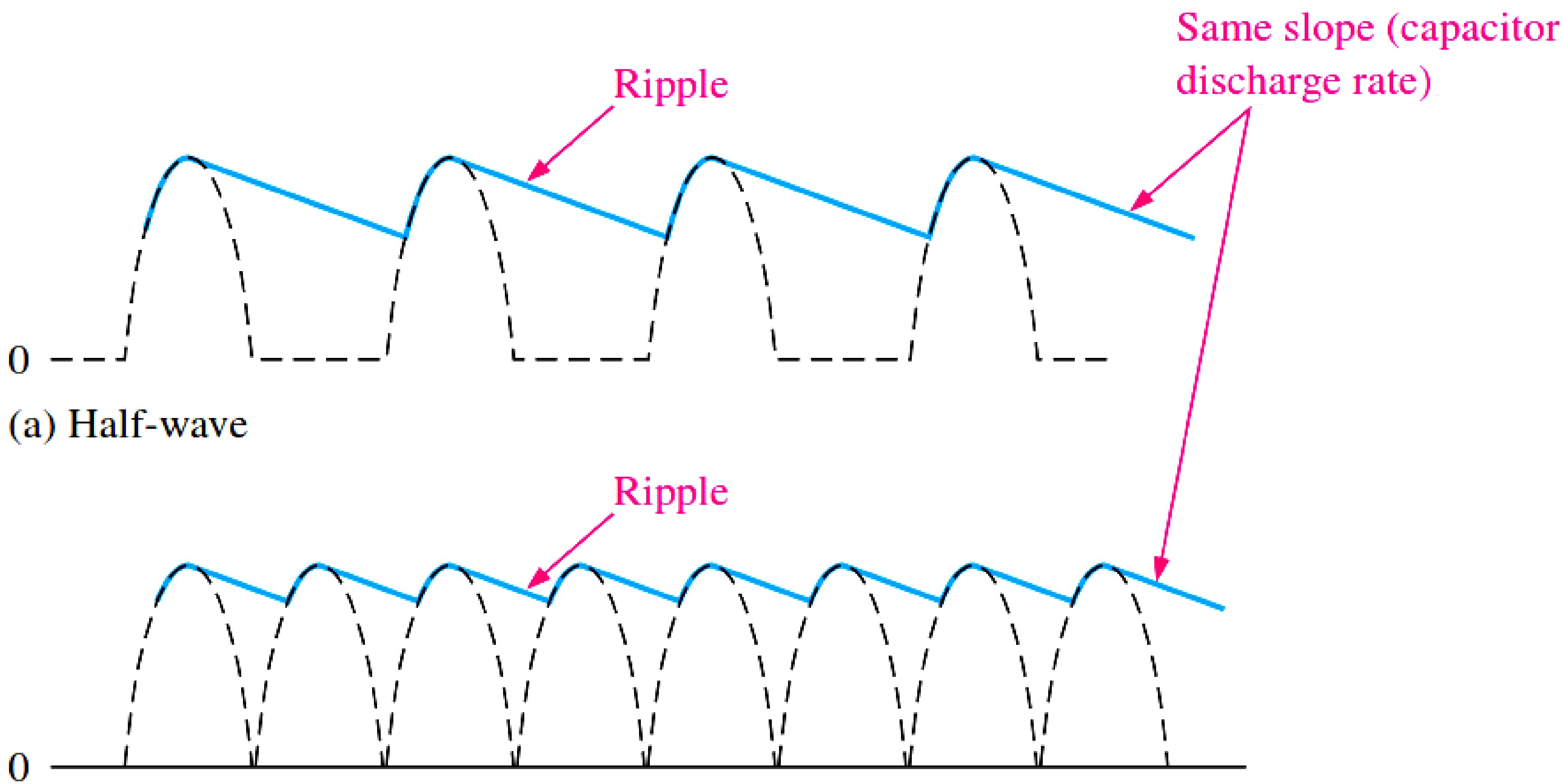
☆ RMS Values of Current and Voltage related to **Peak Value** or **Max Value**.

$$V_{RMS} = \frac{V_{PK}}{\sqrt{2}} \quad , \quad I_{RMS} = \frac{I_{PK}}{\sqrt{2}}$$

$$V_{RMS} = 0.707 \times V_{PK} \quad , \quad I_{RMS} = 0.707 \times I_{PK}$$



The RMS (Root Mean Square) value AC is the value of DC when flowing through a resistor for the specific time period and produces same amount of heat which produced by the AC when flowing through the same circuit for a specific time.



(a) Half-wave

(b) Full-wave

RMS Value of Load Current of HWR

$$I_{RMS} = \frac{I_m}{2}$$

$$\eta = \frac{\mathrm{P_{dc}}}{\mathrm{P_{ac}}}$$

Average Value of Load Current of HWR

$$I_{avg} = \frac{I_m}{\pi}$$

η=40.6 %

Form Factor of HWR

$$\text{Form Factor} = \frac{\text{RMS Value}}{\text{Avg. Value}} = \frac{V_{\text{rms}}}{V_{\text{avg}}}$$

$$\text{Ripple Factor} = \sqrt{(\text{Form Factor})^2 - 1}$$

RF=1.21

RMS Value of Load Current of FWR

$$I_{RMS} = \frac{I_m}{\sqrt{2}}$$

Average Value of Load Current of FWR

$$I_{RMS} = \frac{2I_m}{\pi}$$

Form Factor of FWR

$$\text{Form Factor} = \frac{\text{RMS Value}}{\text{Avg. Value}} = \frac{V_{rms}}{V_{avg}}$$

$$\text{Ripple Factor} = \sqrt{(\text{Form Factor})^2 - 1}$$

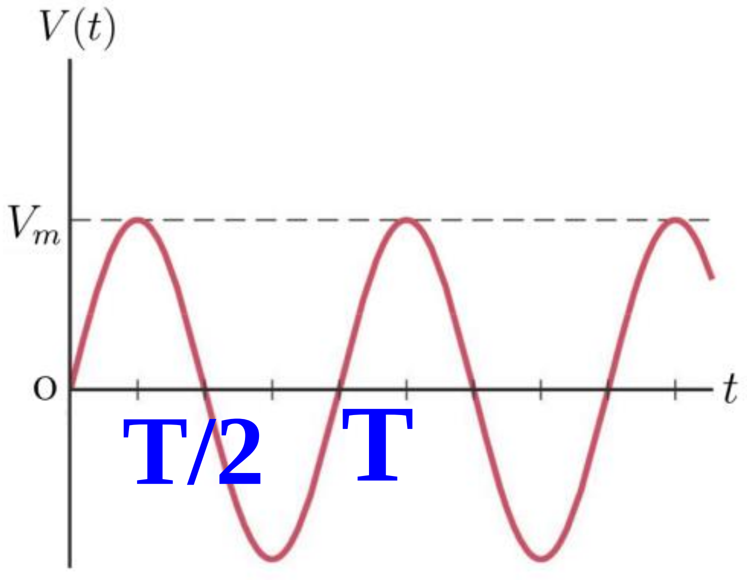
$$\eta = \frac{P_{dc}}{P_{ac}}$$

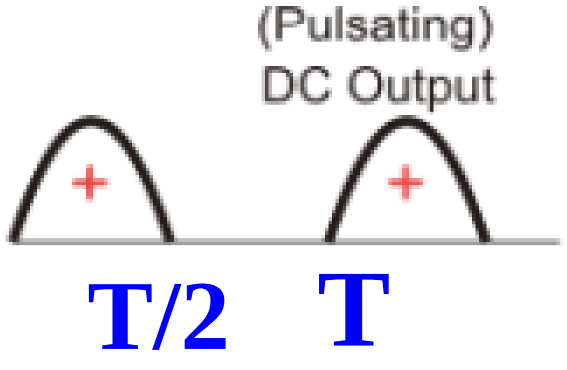
η=81.2 %

RF=0.48

Half Wave Rectifier

$$V_o(t) = \begin{cases} V_m \sin(\omega t), & 0 \le t \le T/2 \\ 0, & T/2 \le t \le T \end{cases}$$





Average voltage of half wave rectifier

$$
\begin{aligned}
V_{\mathrm{dc}} &= \frac{1}{T}\int_0^T V_{\mathrm{o}}(t)\mathrm{d}t \\
&= \frac{1}{T}\int_0^{T/2} V_m \sin(\omega t)\mathrm{d}t + \frac{1}{T}\int_{T/2}^{T} 0\ \mathrm{d}t \\
&= \frac{V_m}{T}\int_0^{T/2} \sin(\omega t)\mathrm{d}t \\
&= \frac{V_m}{T}\left[-\frac{\cos(\omega t)}{\omega}\right]_0^{T/2} \\
&= \frac{V_m}{\omega T}\{-\cos(\omega T/2) + \cos(0)\} \\
V_{\mathrm{dc}} &= \frac{V_m}{\pi}.
\end{aligned}
$$

$$\boxed{\omega = 2\pi/T}$$

$$\{-\cos(\pi) + \cos 0\}$$

RMS value of half wave rectifier

$$
\begin{aligned}
V_{\mathrm{rms}}^2 &= \frac{1}{T}\int_0^T V_{\mathrm{o}}^2(t)\mathrm{d}t \\
&= \frac{V_m^2}{T}\int_0^{T/2} \sin^2(\omega t)\mathrm{d}t + \frac{V_m^2}{T}\int_{T/2}^{T} 0\ \mathrm{d}t \\
&= \frac{V_m^2}{2T}\int_0^{T/2} 2\sin^2(\omega t)\mathrm{d}t \\
&= \frac{V_m^2}{2T}\int_0^{T/2} \{1-\cos(2\omega t)\}\,\mathrm{d}t \\
&= \frac{V_m^2}{2T}\int_0^{T/2} \mathrm{d}t - \frac{V_m^2}{2T}\int_0^{T/2} \cos(2\omega t)\mathrm{d}t \\
&= \frac{V_m^2}{2T}\Big[T\Big]_0^{T/2} - \frac{V_m^2}{2T}\left[\frac{\sin(2\omega t)}{2\omega}\right]_0^{T/2} \\
&= \frac{V_m^2}{4} - \frac{V_m^2}{4\omega T}\Big\{\sin(\omega T) - \sin(0)\Big\} \\
&= \frac{V_m^2}{4}.
\end{aligned}
$$

$$\boxed{\omega = 2\pi/T}$$

$$\boxed{V_{\mathrm{rms}} = \frac{V_m}{2}.}$$

Ripple factor of half wave rectifier

$$\boxed{\gamma = \frac{\text{RMS value of the AC component}}{\text{value of DC component}} = \frac{V_{\mathrm{r(rms)}}}{V_{\mathrm{dc}}}.}$$

$$\gamma = \frac{V_{\mathrm{r(rms)}}}{V_{\mathrm{dc}}} = \sqrt{\left(\frac{V_{\mathrm{rms}}}{V_{\mathrm{dc}}}\right)^2 - 1}$$

$$\gamma = \sqrt{\left(\frac{V_m}{2} \times \frac{\pi}{V_m}\right)^2 - 1} = \sqrt{\left(\frac{\pi}{2}\right)^2 - 1} \approx 1.21.$$

Form factor $= \dfrac{V_{\mathrm{rms}}}{V_{\mathrm{dc}}} = \dfrac{V_m/2}{V_m/\pi} = \dfrac{\pi}{2} \approx 1.57.$

Efficiency of half wave rectifier

$$\boxed{\eta = \frac{\text{DC power output}}{\text{AC power input}} = \frac{P_{\mathrm{dc}}}{P_{\mathrm{ac}}}.}$$

$$P_{\mathrm{ac}} = I_{\mathrm{rms}}^2 (R_L + r_f) = \frac{V_{\mathrm{rms}}^2}{R_L + r_f}.$$

$$P_{\mathrm{dc}} = I_{\mathrm{dc}}^2 R_L = \frac{V_{\mathrm{dc}}^2}{R_L}.$$

Efficiency of half wave rectifier

$$\begin{aligned}
\eta &= \frac{P_{\mathrm{dc}}}{P_{\mathrm{ac}}} \\
&= \frac{V_{\mathrm{dc}}^2}{R_L} \times \frac{R_L + r_f}{V_{\mathrm{rms}}^2} \\
&= \frac{V_{\mathrm{dc}}^2}{V_{\mathrm{rms}}^2} \times \frac{R_L + r_f}{R_L} \\
&= \left(\frac{V_{\mathrm{dc}}}{V_{\mathrm{rms}}}\right)^2 \times \left(1 + \frac{r_f}{R_L}\right) \\
&= \left(\frac{V_m/\pi}{V_m/2}\right)^2 \times \left(1 + \frac{r_f}{R_L}\right) \\
&\approx 0.4053\left(1 + \frac{r_f}{R_L}\right)
\end{aligned}$$

$$P_{\mathrm{ac}} = I_{\mathrm{rms}}^2 (R_L + r_f) = \frac{V_{\mathrm{rms}}^2}{R_L + r_f}.$$

$$P_{\mathrm{dc}} = I_{\mathrm{dc}}^2 R_L = \frac{V_{\mathrm{dc}}^2}{R_L}.$$

$$\boxed{\eta_{\max} \approx 0.4053 = 40.53\%.}$$

Average voltage of Full wave Rectifier

$$V_o(t) = \begin{cases} V_m \sin(\omega t), & 0 \le t \le T/2 \\ V_m \sin(\omega t - \pi), & T/2 \le t \le T \end{cases}$$

$$\begin{aligned}
V_{\text{avg}} &= \frac{1}{T/2}\int_0^{T/2} V(t)\mathrm{d}t \\
&= \frac{2V_m}{T}\int_0^{T/2} \sin(\omega t)\mathrm{d}t \\
&= \frac{2V_m}{T}\left[-\frac{\cos(\omega t)}{\omega}\right]_0^{T/2} \\
&= \frac{2V_m}{\omega T}\{-\cos(\omega T/2) + \cos 0\} \\
&= \frac{2V_m}{2\pi}\{-\cos(\pi) + \cos 0\} \\
&= \frac{V_m}{\pi}(+1+1) \\
&= \frac{2}{\pi}V_m \\
&\approx 0.637\, V_m.
\end{aligned}$$

RMS value of Full wave rectifier

$$
\begin{aligned}
V_{\text{rms}}^2 &= \frac{V_m^2}{T}\int_0^T \sin^2(\omega t)\mathrm{d}t \\
&= \frac{V_m^2}{2T}\int_0^T 2\sin^2(\omega t)\mathrm{d}t \\
&= \frac{V_m^2}{2T}\int_0^T \{1-\cos(2\omega t)\}\,\mathrm{d}t \\
&= \frac{V_m^2}{2T}\int_0^T \mathrm{d}t - \frac{V_m^2}{T}\int_0^T \cos(2\omega t)\mathrm{d}t \\
&= \frac{V_m^2}{2T}\Big[T\Big]_0^T - \frac{V_m^2}{2T}\left[\frac{\sin(2\omega t)}{2\omega}\right]_0^T \\
&= \frac{V_m^2}{2} - \frac{V_m^2}{4\omega T}\Big\{\sin(2\omega T)-\sin(0)\Big\} \\
&= \frac{V_m^2}{2} - \frac{V_m^2}{4\omega T}\Big\{\sin(4\pi)-\sin(0)\Big\} \\
&= \frac{V_m^2}{2} - \frac{V_m^2}{4\omega T}(0-0) \\
&= \frac{V_m^2}{2}.
\end{aligned}
$$

$$\boxed{V_{\text{rms}} = \frac{V_m}{\sqrt{2}} \approx 0.707\,V_m.}$$

Ripple factor of full wave rectifier

$$\begin{aligned}\gamma &= \sqrt{\left(\frac{V_{\mathrm{rms}}}{V_{\mathrm{dc}}}\right)^2 - 1} \\ &= \sqrt{\left(\frac{\pi}{2\sqrt{2}}\right)^2 - 1} \\ &\approx 0.48\end{aligned}$$

$$\text{Form factor} = \frac{V_{\mathrm{rms}}}{V_{\mathrm{dc}}} = \frac{\pi}{2\sqrt{2}} \approx 1.11.$$

Efficiency of Full wave rectifier

$$\eta = \frac{P_{\rm dc}}{P_{\rm dc}}$$

$$= \left(\frac{V_{\rm dc}}{V_{\rm rms}}\right)^2 \times \left(1 + \frac{r_f}{R_L}\right)$$

$$\approx 0.8106 \left(1 + \frac{r_f}{R_L}\right)$$

$$V_{\rm dc} \approx 0.637\, V_m.$$

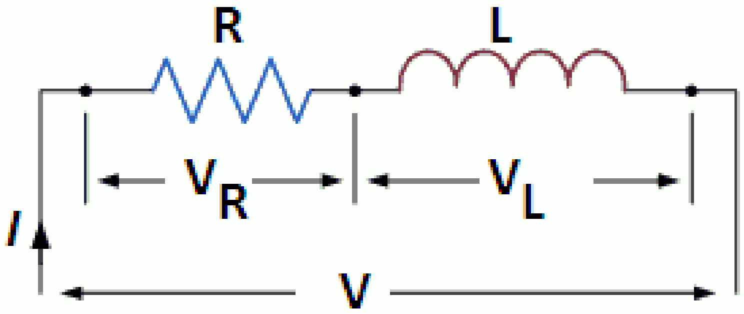
$$\boxed{V_{\rm rms} = \frac{V_m}{\sqrt{2}} \approx 0.707\, V_m.}$$

$$\boxed{\eta_{\rm max} \approx 0.8106 = 81.06\%.}$$

Comparison of Rectifiers

Parameters	Half wave rectifier	Full wave rectifier
Number of diodes	1	2 or 4
Maximum efficiency	40.53%	81.06 %
Peak inverse voltage	V_m	V_m or $2V_m$
Average voltage no load	V_m/π	$2V_m/\pi$
V_{rms} no load	$V_m/2$	$V_m/\sqrt{2}$
Ripple factor	1.21	0.48
Form factor	1.57	1.11
Output frequency	f	$2f$

RL Circuits

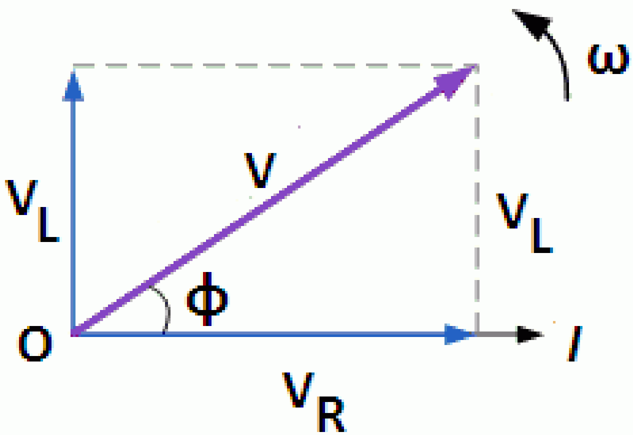


$$V = \sqrt{(IR)^2 + (IX_L)^2}$$

$$I = \frac{V}{\sqrt{(R)^2 + (X_L)^2}} = \frac{V}{Z}$$

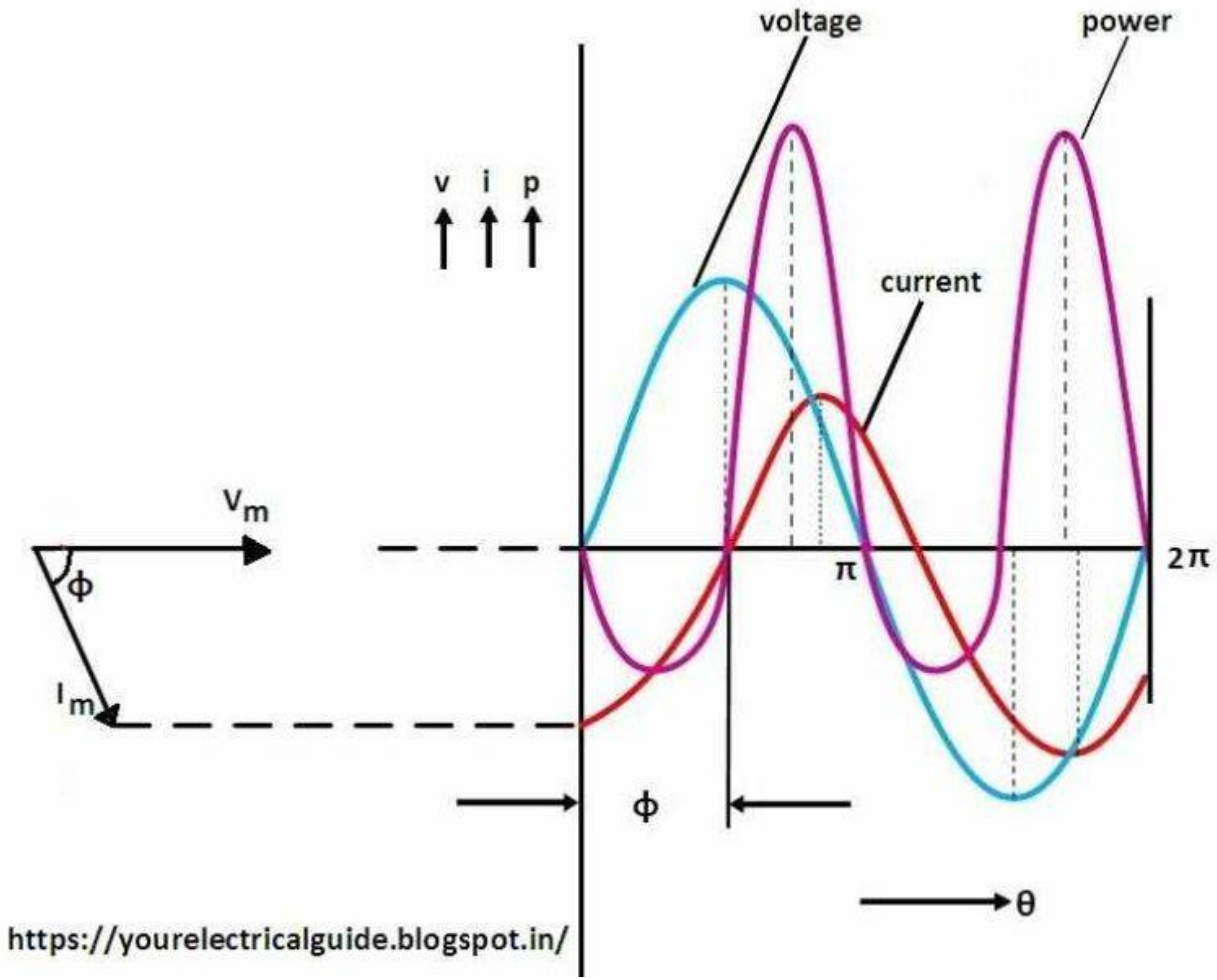
where $Z = \sqrt{(R)^2 + (X_L)^2}$

is called impedance



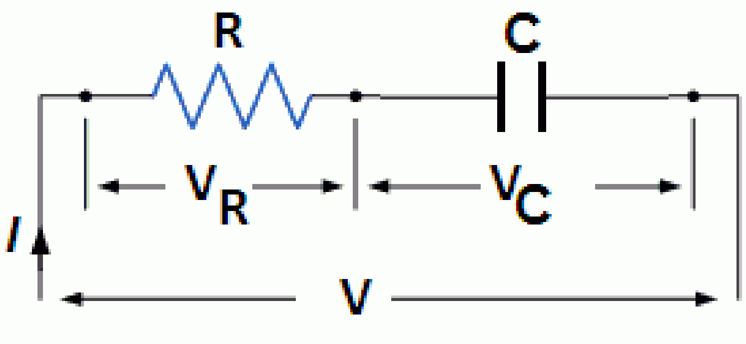
$\phi = \tan^{-1}\dfrac{X_L}{R}$. Power, $P = VI \cos \varphi$

RL Circuits



voltage
power
v i p
current
V_m
ϕ
π
2π
I_m
ϕ
θ
https://yourelectricalguide.blogspot.in/

RC Series Circuit

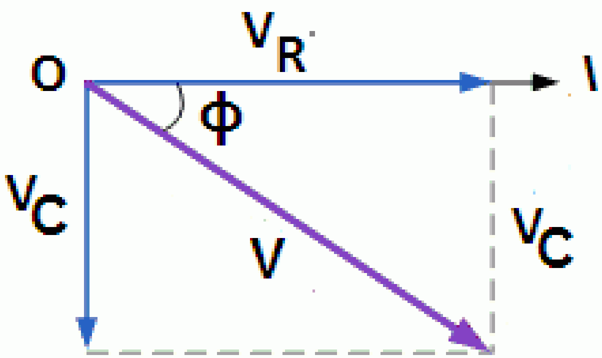


$$V = \sqrt{(IR)^2 + (IX_C)^2}$$

$$I = \frac{V}{\sqrt{(R)^2 + (X_C)^2}} = \frac{V}{Z}$$

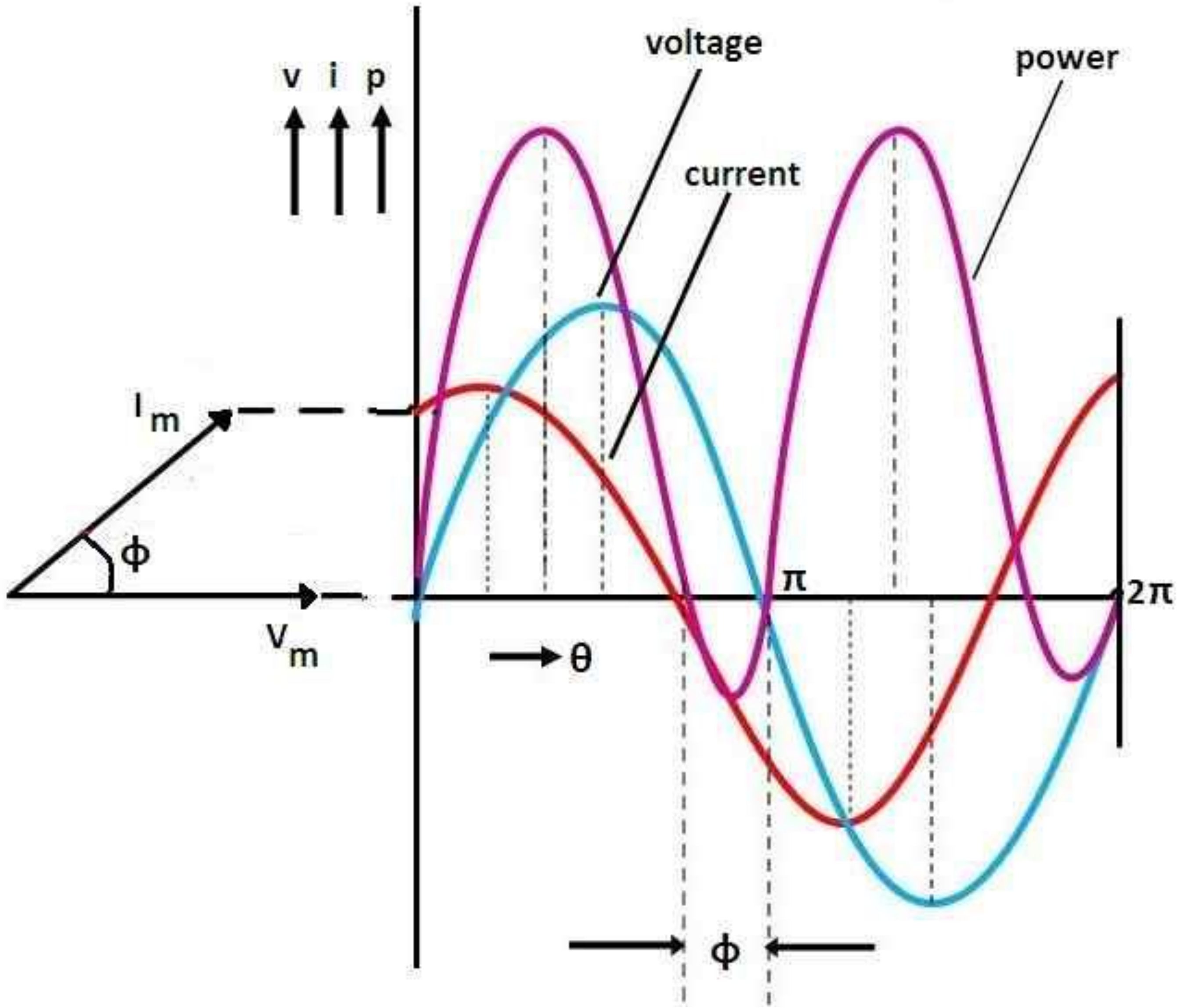
where $Z = \sqrt{(R)^2 + (X_C)^2}$

is called impedance

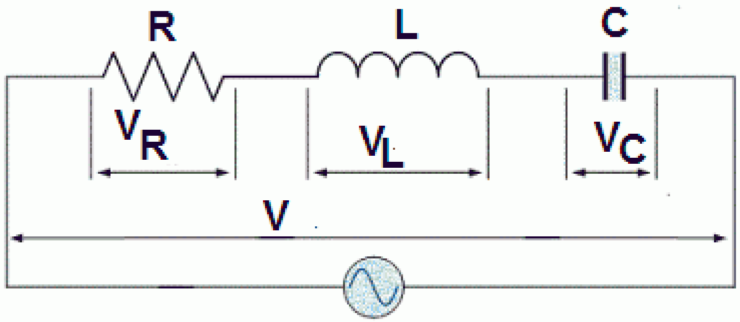


$\phi = \tan^{-1} \frac{X_C}{R}$ Power, $P = VI \cos \varphi$

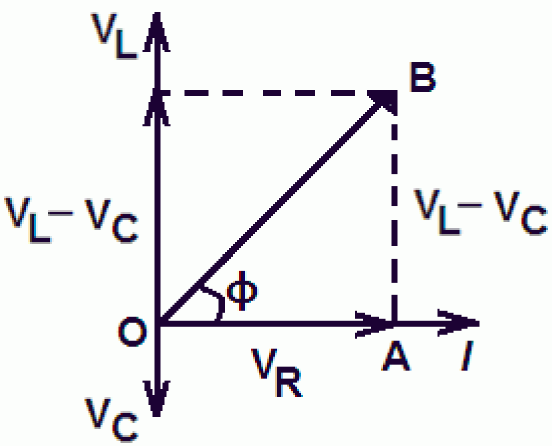
RC Series Circuit



RLC Circuit



RLC Series Circuit



Phasor diagram $X_L > X_C$

$$V = \sqrt{(IR)^2 + I^2(X_L - X_c)^2}$$

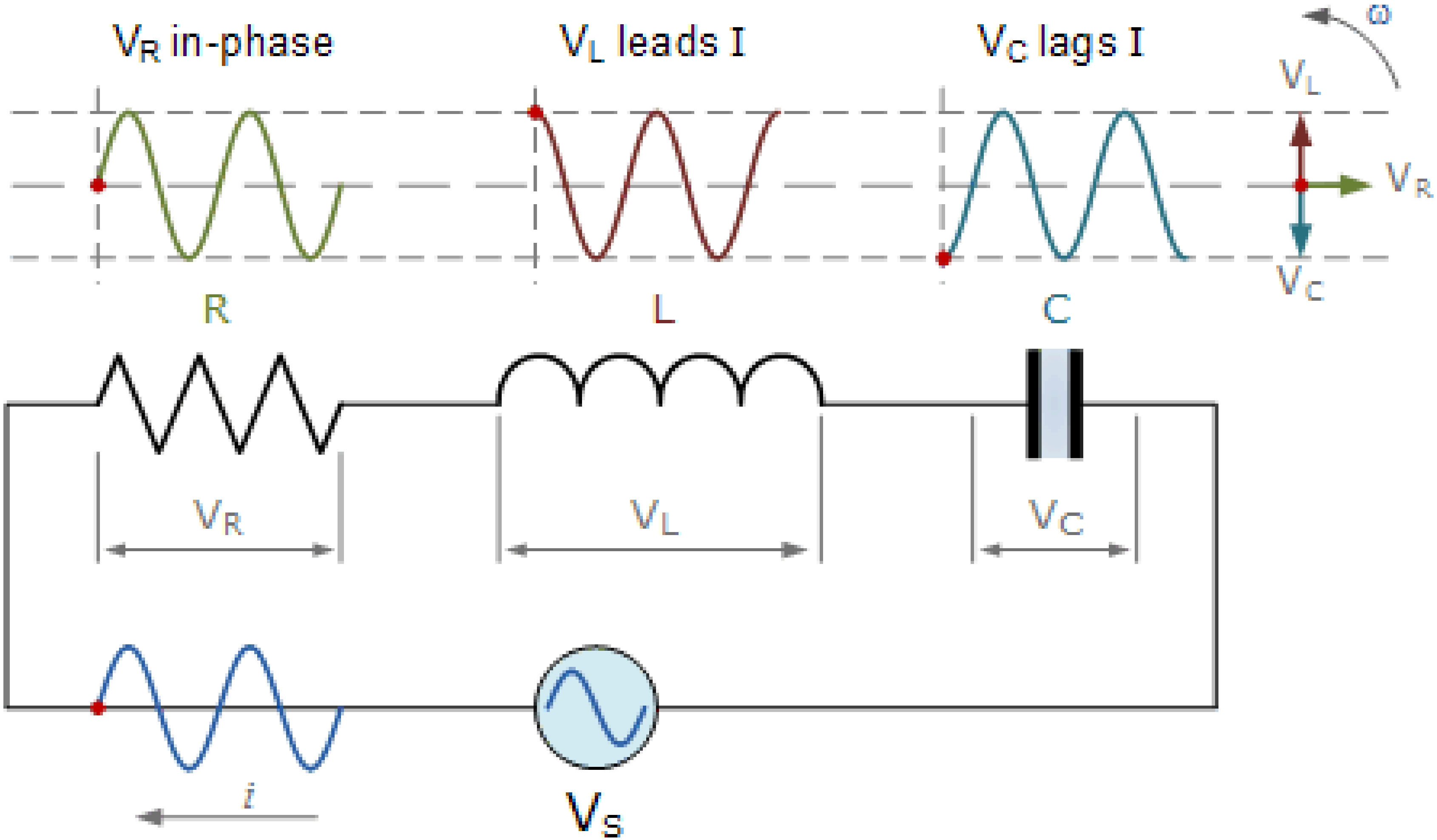
$$I = \frac{V}{\sqrt{(R)^2 + (X_L - X_c)^2}} = \frac{V}{Z}$$

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

is called impedance

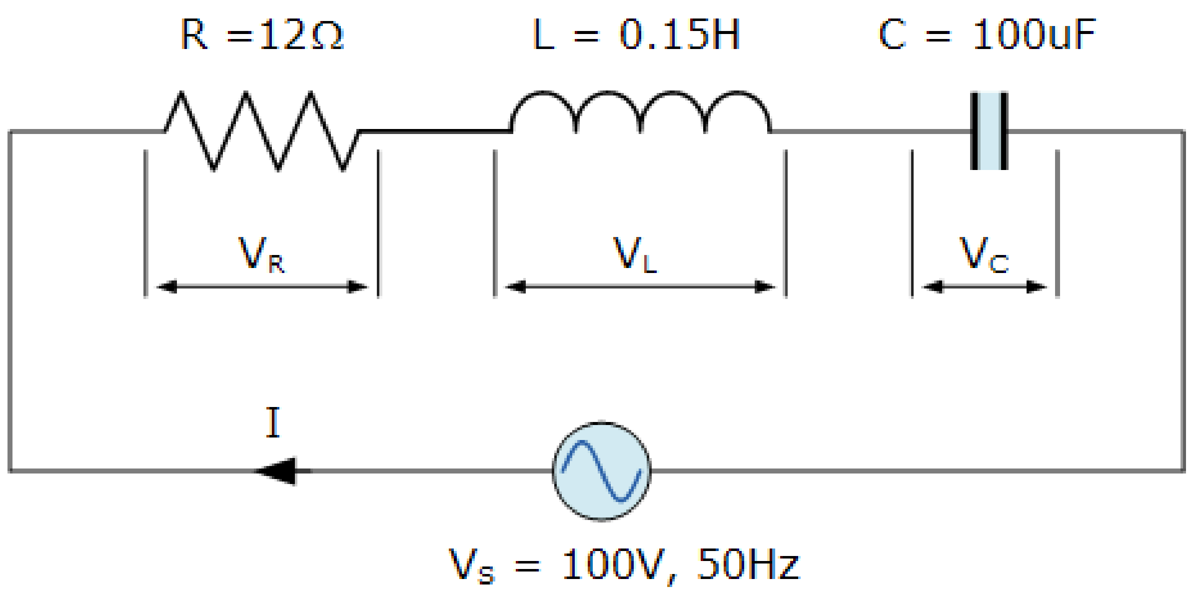
$\phi = \tan^{-1}\frac{X}{R}$ Power, $P = VI \cos \varphi$

where $X = X_L - X_c$



VR in-phase
VL leads I
VC lags I
ω
VL
VR
VC
R
L
C
VR
VL
VC
i
VS

A series RLC circuit containing a resistance of 12Ω, an inductance of 0.15H and a capacitor of 100uF are connected in series across a 100V, 50Hz supply. Calculate the total circuit impedance, the circuits current, power factor.



Inductive Reactance, X_L.

$$X_L = 2\pi fL = 2\pi\times50\times0.15 = 47.13\Omega$$

Capacitive Reactance, X_C.

$$X_C = \frac{1}{2\pi fC} = \frac{1}{2\pi\times50\times100\times10^{-6}} = 31.83\Omega$$

Circuit Impedance, Z.

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

$$Z = \sqrt{12^2 + (47.13 - 31.83)^2}$$

$$Z = \sqrt{144 + 234} = 19.4\Omega$$

Circuits Current, I.

$$I = \frac{V_S}{Z} = \frac{100}{19.4} = 5.14\,\text{Amps}$$

Voltages across the Series RLC Circuit, V_R, V_L, V_C.

$$V_R = I \times R = 5.14 \times 12 = 61.7\ \text{volts}$$

$$V_L = I \times X_L = 5.14 \times 47.13 = 242.2\ \text{volts}$$

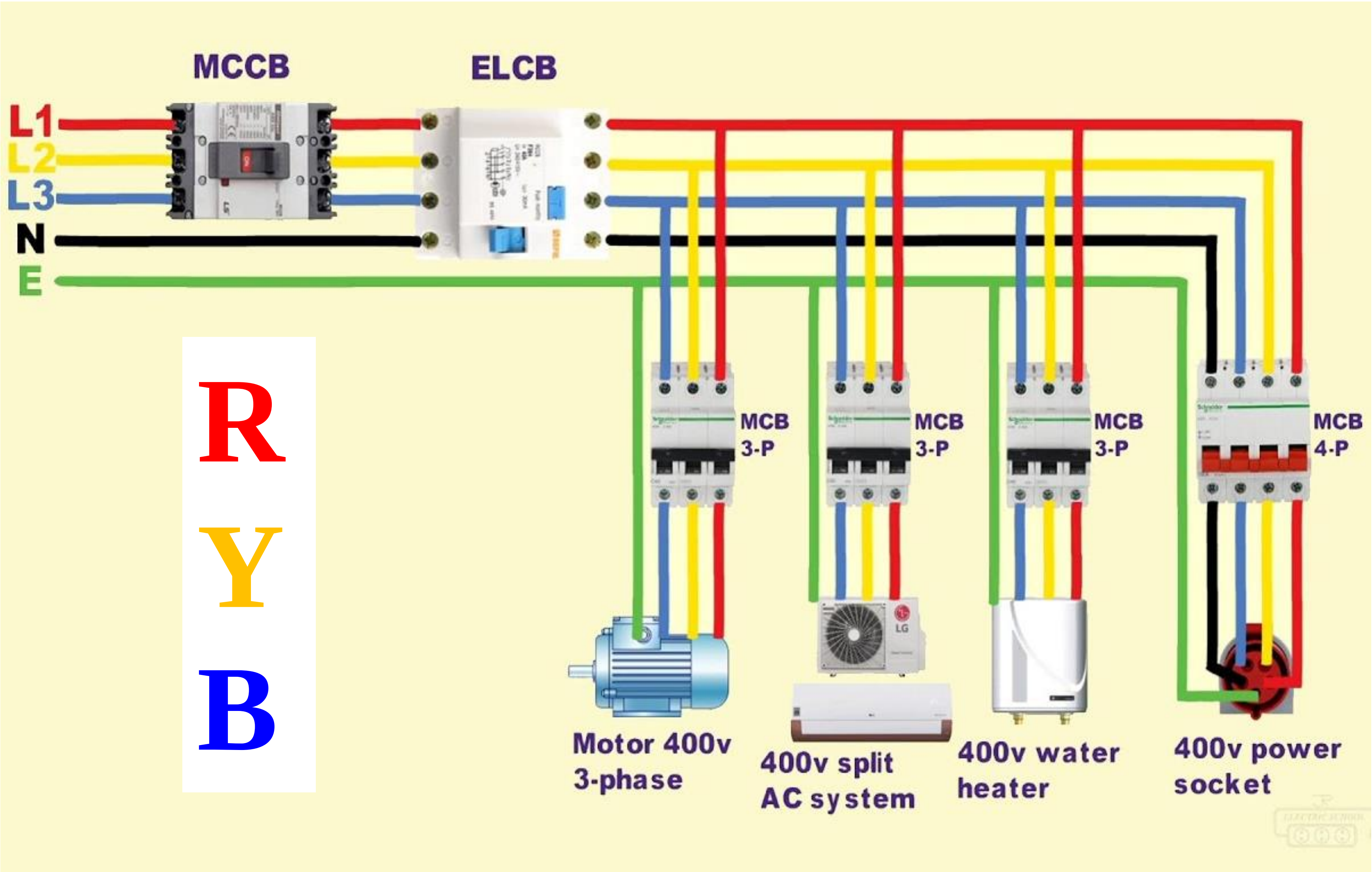
$$V_C = I \times X_C = 5.14 \times 31.8 = 163.5\ \text{volts}$$

Circuits Power factor and Phase Angle, θ.

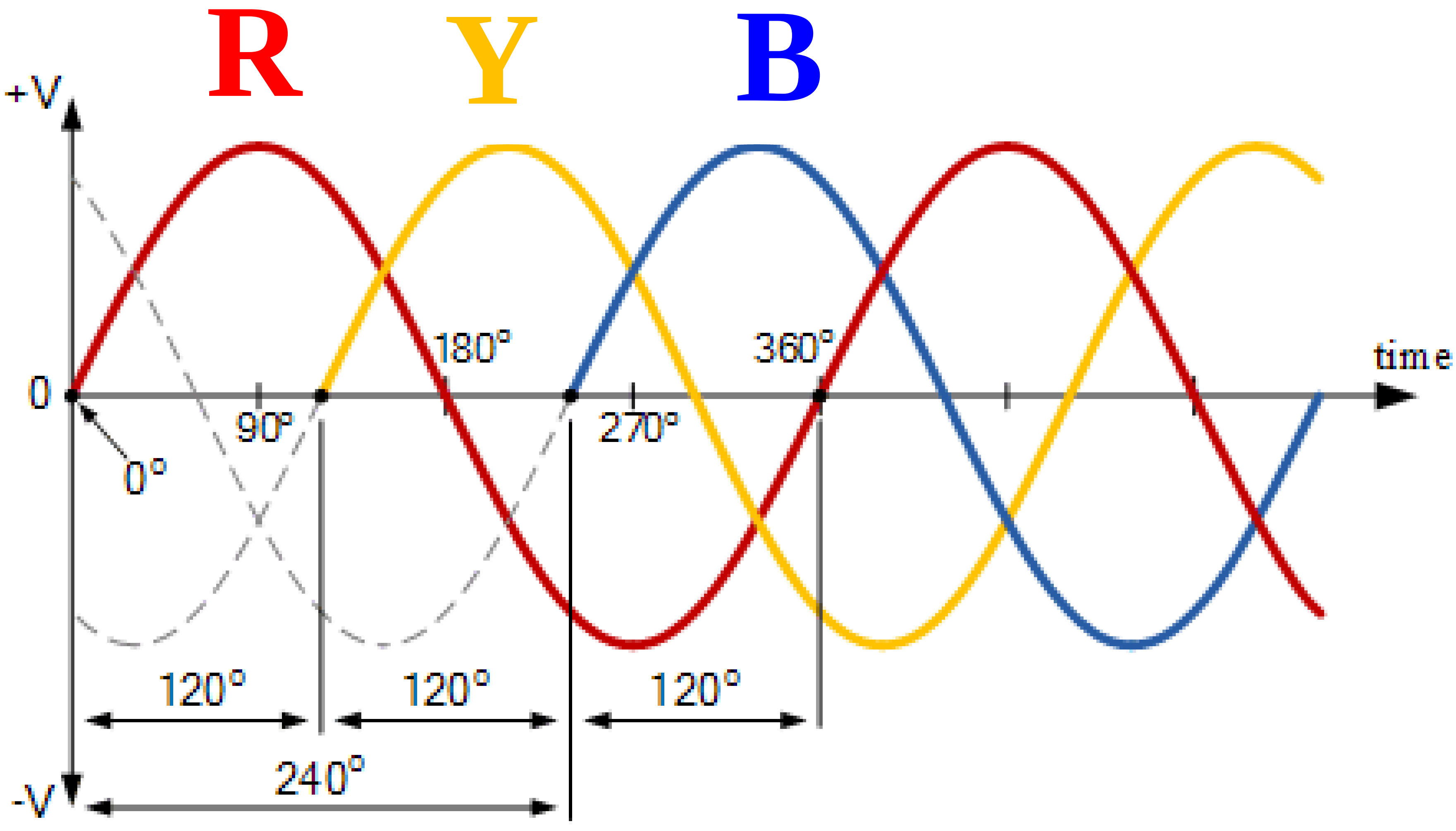
$$\cos\phi = \frac{R}{Z} = \frac{12}{19.4} = 0.619$$

$$\therefore \cos^{-1} 0.619 = 51.8^{0} \text{ lagging}$$

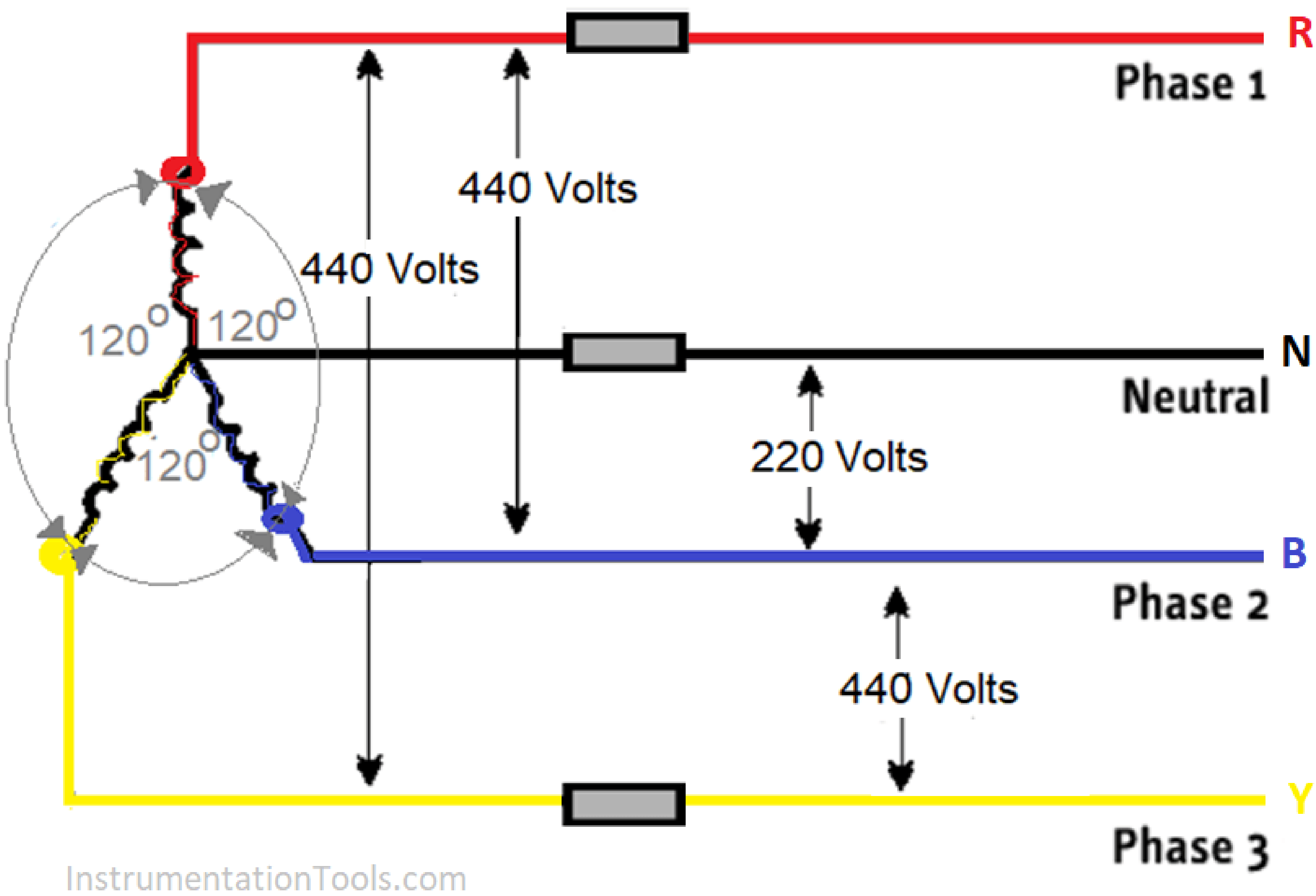
3 Phase AC Circuit



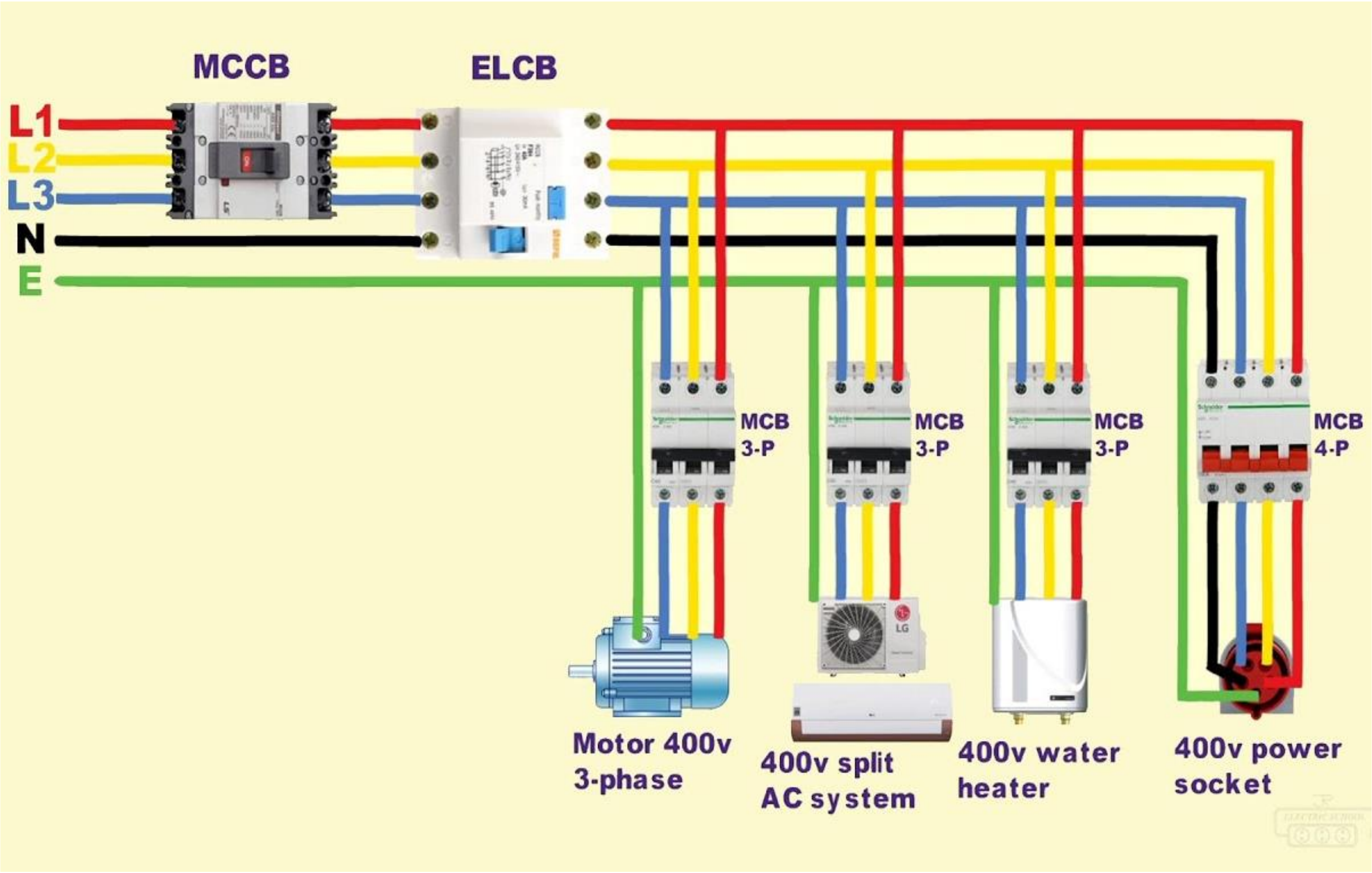
3-Phase Waveform



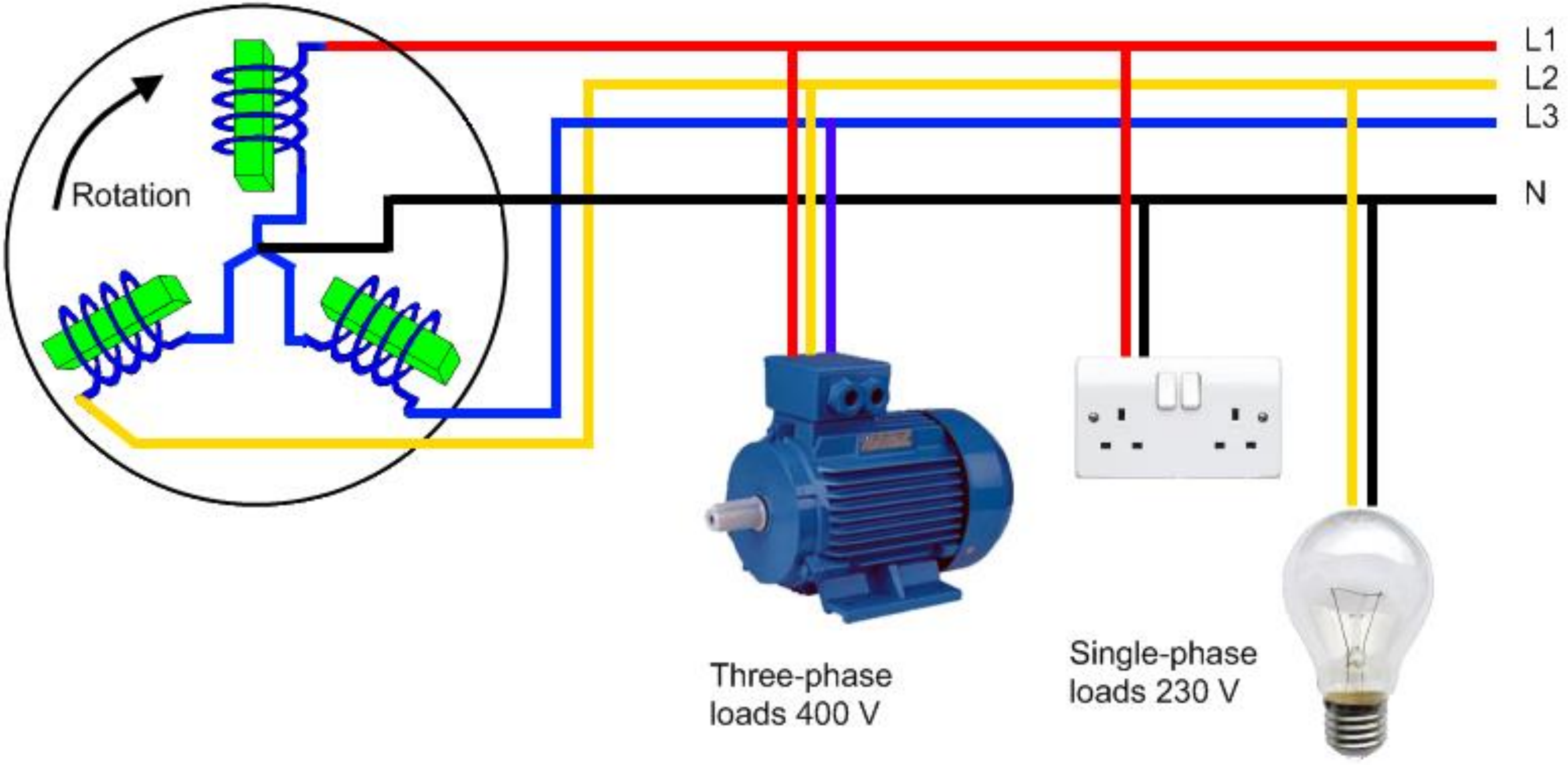
3-Phase Voltage



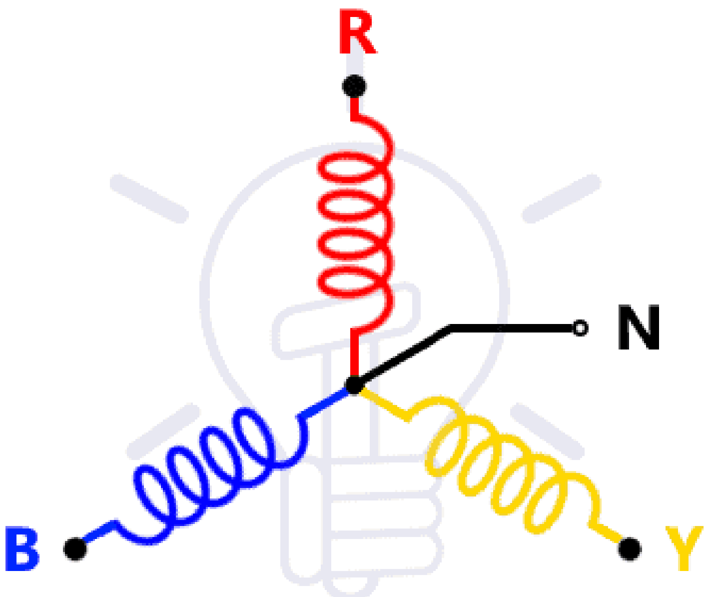
Balanced Load



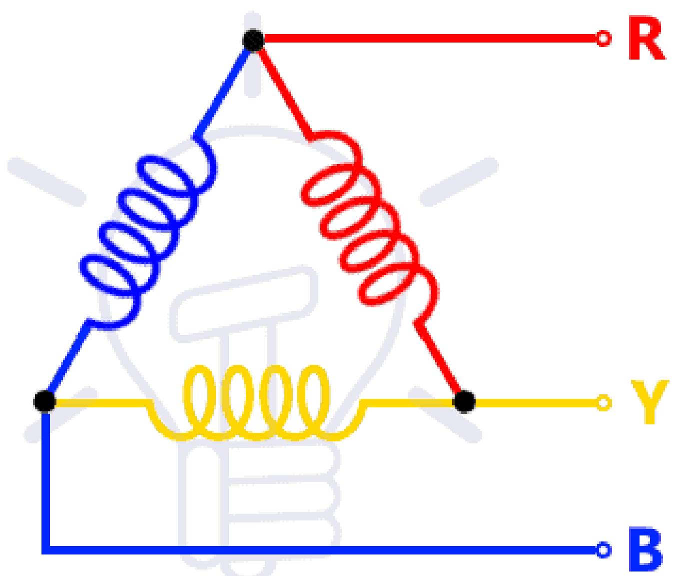
Unbalanced Load



3 Phase Load

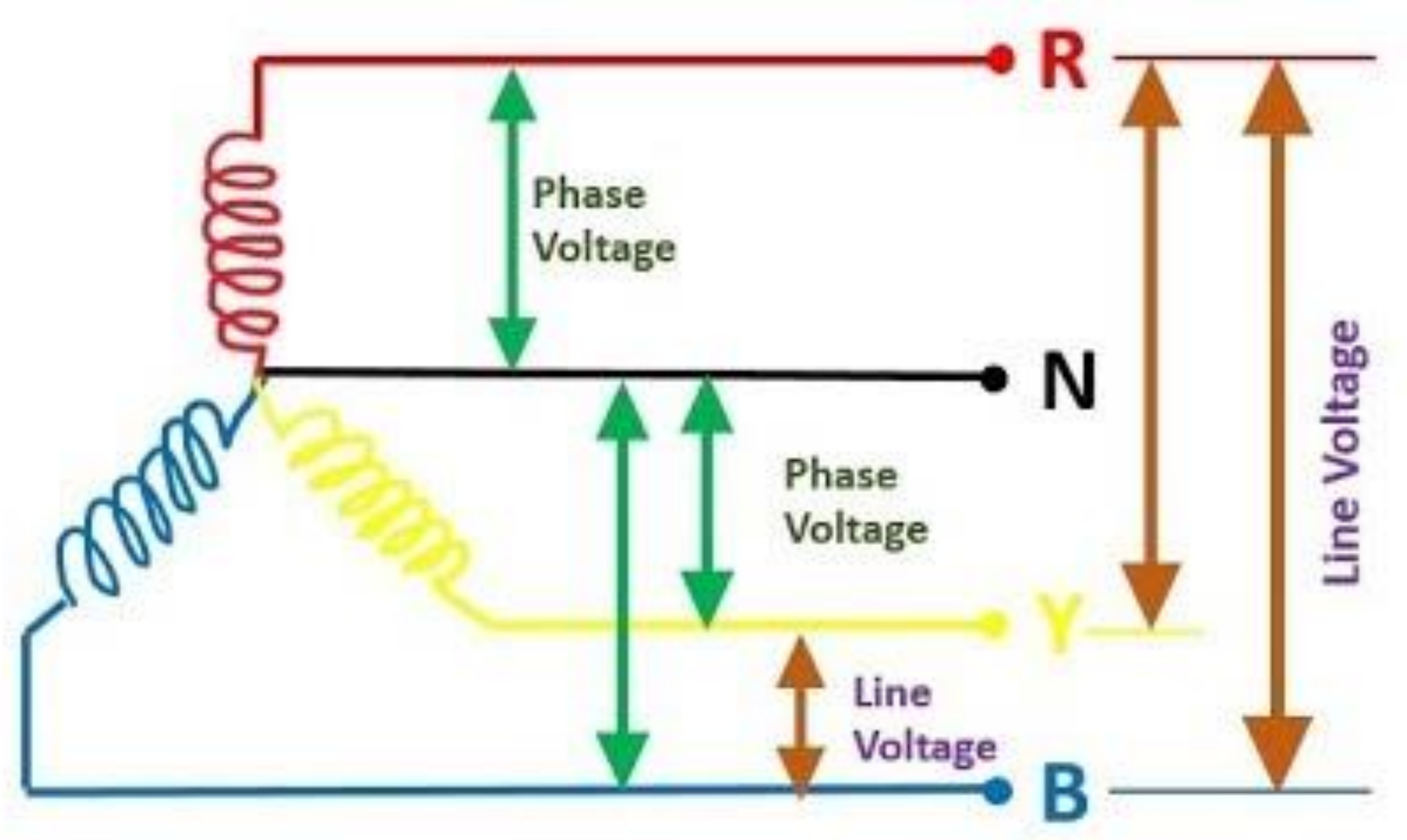


STAR (Y)

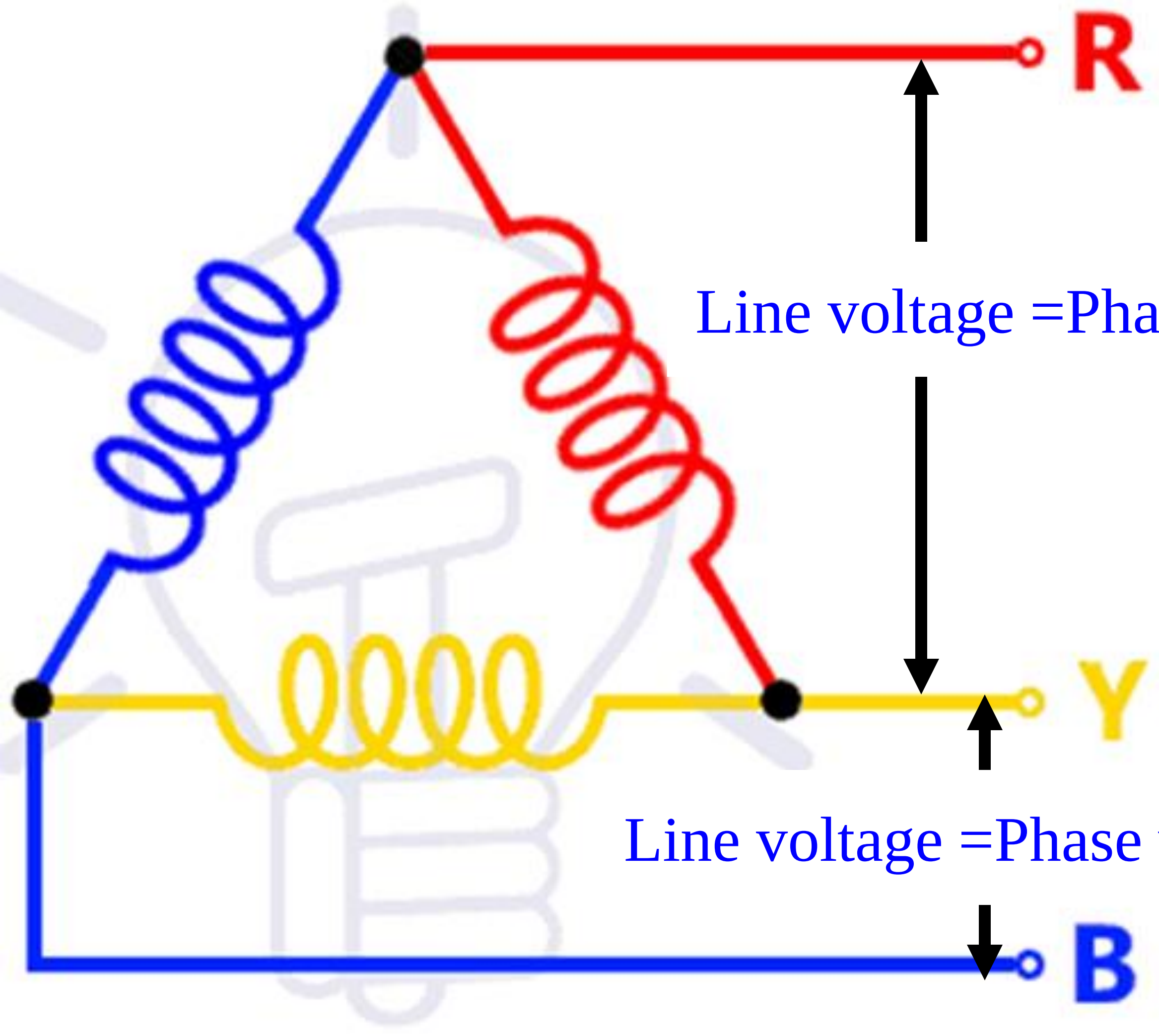


DELTA (Δ)

Star Load


R
Phase
Voltage
N
Phase
Voltage
Line Voltage
Y
Line
Voltage
B

Delta Load



Line voltage =Phase voltage

Line voltage =Phase voltage

3-Phase Formulas

	Star	Delta
Voltage	$V_{Line} = \sqrt{3} \times V_{Phase}$	$V_{Line} = V_{Phase}$
Current	$I_{Line} = I_{Phase}$	$I_{Line} = \sqrt{3} \times I_{Phase}$

$$Power = \sqrt{3} V_{Line} I_{Line} Cos\phi$$

Total Phase Power=$V_P I_P COS\phi$

Total line Power=$V_L I_L COS\phi$

Three similar coils each of resistance 10 Ω and an inductance of 0.05H are connected in star and delta to three phase 400V,50Hz symmetrical system. Find the phase current, line current, total phase power & total line power?

Given: R=10 Ω,

L=0.05H,

V=400

f=50 Hz

STAR CONNECTION:-

$$V_L = \sqrt{3}\, V_p$$

$$X_L = 2\pi f L$$

$$\therefore V_p = \frac{400}{\sqrt{3}} = 231\ V.$$

Impedance, $Z = \sqrt{R^2 + X_L^2} = \sqrt{10^2 + (15.7)^2}$

$$Z = 18.61 \angle 57.6^\circ.$$

W.K.t $I_p = \frac{V_p}{18.61} = \underline{\underline{12.41\ A}}$

Total 3ϕ power $= V_p\, I_p \cos\phi$

W.K.t $I_p = \dfrac{V_p}{18.61} = \underline{\underline{12.41\,A}}$

$\Rightarrow$ Total 3ϕ power $= V_p \cdot \dfrac{V_p}{18.61} \cdot \cos 57.6 \Rightarrow \underline{4608\,W}$.

Line Power $\Rightarrow V_L\, I_L \cos\phi$.

$= (\sqrt{3} \cdot V_p) \, I_p \cdot \cos\phi$

$= (\sqrt{3} \cdot 400) \left(\dfrac{231}{18.61}\right) \cos(57.6^\circ) = \underline{4608\ W}$

(ii) DELTA CONNECTION:-

$V_L = V_{ph}$; $I_L = \sqrt{3}\, I_{ph}$.

Total 3ϕ power $= V_p I_p \cos\phi$

$$= (400)\left(\frac{400}{18.61}\right)\cos 57.6^\circ.$$

$$= \underline{4608\,W.}$$

Line Power $= V_L I_L \cos\phi$

$$= (400)\cdot\sqrt{3}\cdot\left(\frac{400}{18.61}\right)\cdot\cos 57.6^\circ.$$

$$= \underline{7970\,W.}$$