General Equations

- KCL: $\sum I_{in} = \sum I_{Out} \rightarrow$ Node's Input Current = Node's Output Current
- KVL: $\sum V = 0 \rightarrow$ Voltage across a loop totals to 0.
- Ohm's Law: $V = IR$

Phasors

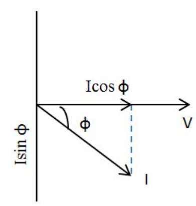
Phasors will only show us the steady state response of the circuit, not the transient response.
Eq: $v(t) = V_M \cos(\omega t + \theta) \leftrightarrow \bar{V} = V_M \angle \theta_v = V_M e^{\jmath \theta_v} = V_M (\cos\theta_v + \jmath \sin\theta_v)$
You can use phasors with Nodal Analysis, Mesh/Loop Analysis, Superposition, and Thevenin and Norton Equivalencies.

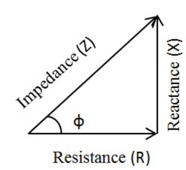
$z_1 = x_1 + \jmath y_2 = r_1 \angle \phi_1,\ z_2 = x_2 + \jmath y_2 = r_2 \angle \phi_2$

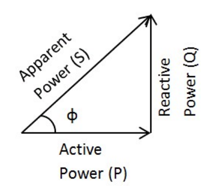
Addition	$z_1 + z_2 = (x_1 + x_2) + \jmath (y_1 + y_2)$
Subtraction	$z_1 - z_2 = (x_1 - x_2) + \jmath (y_1 - y_2)$
Multiplication	$z_1 z_2 = r_1 r_2 \angle (\phi_1 + \phi_2)$
Division	$\frac{z_1}{z_2} = \frac{r_1}{r_2} \angle (\phi_1 - \phi_2)$
Reciprocal	$\frac{1}{z_1} = \frac{1}{z_1} \angle - \phi_1$
Square Root	$\sqrt{z_1} = \sqrt{r_1} \angle \frac{\phi_1}{2}$
Complex Conjugate	$z_1^* = x - \jmath y = r \angle - \phi_1 = r e^{-\jmath \phi_1}$

RMS/Complex Power/Max Power Transfer

- $X_{rms} = \sqrt{\frac{1}{T} \int_0^T x(t)^2 dt}$
- $P_{avg} = \frac{1}{2} \mathrm{Re}\{\mathbf{V}\mathbf{I}^*\} = \frac{1}{2} V_m I_m \cos(\theta_v - \theta_i)$
- $\mathbf{S} = I_{rms}^2 \mathbf{Z} = \frac{V_{rms}^2}{\mathbf{Z}^*} = \mathbf{V}_{rms} \mathbf{I}_{rms}^*$
- $\sum_{k=1}^n S_k$
- $C = \frac{Q_C}{\omega V_{rms}^2} = \frac{P(\tan\theta_1 - \tan\theta_2)}{\omega V_{rms}^2}$
- $L = \frac{V_{rms}^2}{\omega (Q_1 - Q_2)}$







Name	Symbol	Equation(s)	Units
Complex Power	$\mathbf{S}$	$\frac{P}{Pf} \angle \arccos(Pf) = P + \jmath Q = \mathbf{V}_{rms} \mathbf{I}_{rms}^* = \lvert \mathbf{V}_{rms} \rvert \lvert \mathbf{I}_{rms} \rvert \angle (\theta_v - \theta_i)$	VA
Apparent Power	S	$\lVert \mathbf{S} \rVert = \lvert \mathbf{V}_{rms} \rvert \lvert \mathbf{I}_{rms} \rvert = \sqrt{P^2 + Q^2}$	VA
Real Power	P	$\mathrm{Re}\{\mathbf{S}\} = \mathbf{S} * Pf = \mathbf{S} \cos(\theta_v - \theta_i)$	W
Reactive (Imaginary) Power	Q	$\mathrm{Im}\{\mathbf{S}\} = S \sin(\theta_v - \theta_i)$	VAR
Power Factor	Pf	$\frac{P}{S} = \cos(\theta_v - \theta_i)$	Lead/Lag

Elements

Methods to Solve Equations

Nodal Analysis

1. # of Nodes? $\rightarrow n$
2. Make one node the reference node. Assign $n-1$ nodal voltages
3. For a **voltage** source, write a CONSTRAINT EQUATION (Con. Eq.). If there is a voltage source between 2 non-reference nodes, make that a **SUPERNODE**.
4. Write KCL at each node. $(n-1)$ equations.
5. Solve Equations.

Relation	R	C	L
v-i i-v	$V = IR$ $I = \frac{V}{R}$	$v = \frac{1}{C}\int_{t_0}^{t} i(x)dx + v(t_0)$ $i = C\frac{dv}{dt}$	$v = L\frac{di}{dt}$ $i = \frac{1}{L}\int_{t_0}^{t} v(x)dx + i(t_0)$
P or W	$P = I^2R = \frac{V^2}{R}$	$P = \frac{1}{2}Cv_c^2$	$W = \frac{1}{2}Li_l^2$
Series Parallel	$R_{eq} = R_1 + R_2 + \ldots + R_n$ $\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots + \frac{1}{R_n}$	$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \ldots + \frac{1}{C_n}$ $C_{eq} = C_1 + C_2 + \ldots + C_n$	$L_{eq} = L_1 + L_2 + \ldots + L_n$ $\frac{1}{L_{eq}} = \frac{1}{L_1} + \frac{1}{L_2} + \ldots + \frac{1}{L_n}$
@ Steady State	Same (Nothing Happens)	Open Circuit	Short Circuit
Phasors	$Z_R = R$	$Z_C = \frac{1}{j\omega C}$	$Z_L = j\omega L$

Mesh/Loop Analysis

1. # of Nodes? $\rightarrow n$ # of Branches? $\rightarrow b$ # of meshes/loops? $\rightarrow b - n + 1 = l$
2. Assign l loop currents.
3. For **current** sources, write a CONSTRAINT EQUATION (Con. Eq.). If there is a current source between 2 meshes, that's a **SUPERMESH**.
4. Write KVL for each mesh.
5. Solve Equations.

Superposition

- # of sources, n, determines the number of equations you will have.
- Shut off each source, one at a time, solving for the term that you want.
  - Voltage Source = S.C.
  - Current Source = O.C.
- Sum each of the individual terms together. $\sum_{i=1}^{n} x_i$
- **THIS IS THE ONLY WAY TO SOLVE FOR A CIRCUIT WITH MULTIPLE SOURCES!!**

Source Transformations

ALL source transformations obey Ohm's Law. $V = IR$. This will **ONLY** work on impedances in series with **VOLTAGE** sources, or impedances in parallel with **CURRENT** sources.

Thevenin and Norton Equivalencies

- ONLY independent sources - Zero all sources, find $\mathbf{Z}_{eq}$.
  - 0-ing Current Sources = O.C., 0-ing Voltage Sources = S.C.
  - Look at circuit from load's perspective for $\mathbf{Z}_{eq}$
  - $\mathbf{V}_{Th} = \mathbf{V}_{OC}$, $\mathbf{I}_N = \mathbf{I}_{SC}$
- BOTH dependent and independent sources
  - Find $\mathbf{V}_{Th} = \mathbf{V}_{OC}$, $\mathbf{I}_N = \mathbf{I}_{SC}$
  - Solve $\mathbf{Z}_{Th} = \frac{\mathbf{V}_{OC}}{\mathbf{I}_{SC}}$
- ONLY dependent sources
  - $\mathbf{V}_{Th} = 0$, $\mathbf{I}_N = 0$
  - $\mathbf{Z}_{Th} = \mathbf{Z}_N \rightarrow$ Attach test source @ load.
    * If voltage test source, find current. If current test source, find voltage
  - $\mathbf{Z}_{Th} = \frac{\mathbf{V}_{Test}}{\mathbf{I}_{Test}}$

Maximum Power Transfer - AC

- $\mathbf{Z}_{Load} = \mathbf{Z}_{Th}^*$, $R_{Th} = \text{Re}\{\mathbf{Z_{Th}}\}$, $R_L = |\mathbf{Z}_{Th}| = \sqrt{R_{Th}^2 + (X_{Th} + X_L)^2}$
- $P_{max} = \frac{|\mathbf{V}_{Th}|^2}{8R_{Th}}$