• Use PHASORS to represent sinusoids (of a given frequency)
  Polar Form $A + jB$
  Rect Form $M/\theta$
  Graphical Interpretation:

• Sinusoidal Steady-State Analysis
  Time Domain
  $u(t) = V_m \cos(\omega t + \theta)$
  $u = iR$
  Complex Impedances:
  $Z_R = R$
  $Z_L = j\omega L$
  $Z_C = \frac{1}{j\omega C} = -\frac{j}{\omega C}$

• ELI the ICE man
  Voltage leads Current in an Inductor (L)
  Current leads Voltage in a Capacitor (C)

• RMS of $V_m \cos(\omega t + \theta) = \frac{V_m}{\sqrt{2}}$

• All standard circuit analysis techniques can be used in the Phasor domain:
  Node-Voltage Analysis
  Mesh-Current Analysis
  Thevenin/Norton
  Source Transformations
  Superposition
  $V = IZ$
  KCL
  KVL
  Voltage Divider Rule
  Current Divider Rule
• S.S.S. Power Calculations

Power Factor: \( PF = \cos(\Theta) \quad \Theta = \Theta_v - \Theta_i \)

Average Power: \( P = \frac{V_{\text{rms}}I_{\text{rms}} \cos(\Theta)}{2} \quad [\text{W}] \)

Reactive Power: \( Q = \frac{V_{\text{rms}}I_{\text{rms}} \sin(\Theta)}{2} \quad [\text{VAR}] \)

"Lagging" Power Factor \( \Rightarrow \) current lags voltage \( \Rightarrow \) INDUCTIVE load

"Leading" Power Factor \( \Rightarrow \) current leads voltage \( \Rightarrow \) CAPACITIVE load

Apparent Power: \( V_{\text{rms}}I_{\text{rms}} \quad [\text{VA}] \)
\[ = \sqrt{P^2 + Q^2} \]

Power Triangles

\[ \begin{align*}
& \text{Inductive Load} \quad (Q > 0) \\
& \text{Capacitive Load} \quad (Q < 0) \\
& \text{Purely Resistive Load} \quad (\Theta = Q = 0)
\end{align*} \]

\[ P = |I_{\text{rms}}|^2R \quad \text{or} \quad \frac{|V_{\text{rms}}|^2}{R} \]

\[ Q = |I_{\text{rms}}|^2X \quad \text{or} \quad \frac{|V_{\text{rms}}|^2}{X} \]

\[ I_{\text{rms}} \text{ is current passing through } R \text{ or } X \]

\[ V_{\text{rms}} \text{ is voltage present on } R \text{ or } X \]

• Maximum Power Transfer ("Impedance Matching")

Load should equal complex conjugate of Thevenin impedance seen by load

\( Z_L = Z_{TH}^* \)

or if load is purely resistive

\( Z_L = R_L = \frac{|Z_{TH}|}{\sqrt{R_{TH}^2 + X_{TH}^2}} \)
- Ideal Transformer
  - The side with fewer windings is the "secondary" side
  - POWER IS CONSTANT \( V_1 I_1 = V_2 I_2 \)
  \[
  V_2 = \frac{N_2}{N_1} V_1 \quad \text{or} \quad V_2 = -\frac{N_2}{N_1} V_1 \\
  I_2 = \frac{N_1}{N_2} I_1 \quad \text{or} \quad I_2 = -\frac{N_1}{N_2} I_1
  \]
  
  Rules for determining polarities:
  1. If the coil voltages \( V_1 \) and \( V_2 \) are both positive (or negative) at the dot-marked terminal, use '+'
  2. If the coil currents \( I_1 \) and \( I_2 \) are both directed into (or out of) the dot-marked terminal, use '-'

- Impedance Transformations
  \[
  Z_L' = \left( \frac{N_1}{N_2} \right)^2 Z_L
  \]
  impedance seen by source side of transformer

- Intro to Filters
  Transfer Function: \( H(f) = \frac{V_{\text{out}}(f)}{V_{\text{in}}(f)} \)
  Math definitions:
  \[
  |H(f)| = \sqrt{H(f) \cdot H(f)^*} \quad \angle H(f) = \arctan\left(\frac{\text{Im}\{H(f)\}}{\text{Re}\{H(f)\}}\right)
  \]
  Decibels: \( |H(f)|_{\text{dB}} = 20 \log_{10} |H(f)| \)
  "Decade" ⇒ factor of 10
  "Octave" ⇒ factor of 2
  e.g.: 10Hz → 1000Hz
  e.g.: 10Hz → 80Hz
  "2 Decades"
- **First-Order LPF**

  Example:

  \[
  V_{IN} \quad R \quad V_{OUT}
  \]

  \[\text{Example } H(f): \quad \frac{1}{1+j2\pi f \tau RC}\]

  \[\text{General Form } H(f): \quad \frac{1}{1+j\left(\frac{f}{f_B}\right)}\]

  \[f_B = \frac{1}{2\pi \tau RC} \quad \text{or} \quad \tau = \frac{1}{RC}\]

- **First-Order HPF**

  \[\text{Example } H(f): \quad \frac{j2\pi f \tau RC}{1+j2\pi f \tau RC}\]

  \[\text{General Form } H(f): \quad \frac{j\left(\frac{f}{f_B}\right)}{1+j\left(\frac{f}{f_B}\right)}\]

  \[f_B = \frac{1}{2\pi \tau RC} \quad \text{or} \quad \tau = \frac{1}{RC}\]

  \[\tau = \frac{1}{RC}\]

- **Bode Plots**

  **First-Order LPF**

  \[|H(f)| \text{ vs. } f\]

  \[|\angle H(f)| \text{ vs. } f\]

  \[f_B = \text{Break Freq.; } \text{(} \text{or} \text{''Half-power'' Freq.}\text{)}\]

- **Bandpass Filters** (Resonant Circuits)

  **Resonant Frequency**

  \[\text{Freq. at which impedance is purely resistive}\]

  \[\text{i.e. total reactance is zero}\]

  \[f_0 = \frac{1}{2\pi \sqrt{LC}} \quad \text{same for series or parallel BPF circuits}\]

  **Quality Factor**

  \[Q = \text{measure of magnitude Response's ''Narrowness''}\]

  \[\text{(large } Q \Rightarrow \text{narrow passband)}\]

  \[\text{Bandwidth: } B = f_H - f_L = \frac{f_0}{Q}\]

  \[(\text{small } Q) \quad \text{vs. } (\text{large } Q)\]