Topics for Today:

• Announcements
  • E-mail forum soon available. Use it!
  • Web page: http://www.ece.mtu.edu/faculty/bamork/ee5200/
  • Bring calculator to lectures, for in-class sample calculations.
  • Buy a 3-ring binder for course materials.
  • Office hrs: M,W,F 2-3pm Eastern Time
  • Office: EERC 614. Phone: 906.487.2857
  • Ch.1 Solutions posted on web page, finish review soonest.
  • Set of exercises CKTS posted, due Mon Sept 24th 9am ET.
  • Ch.2 material - aggressively review it, Ch.2 solutions posted.

• Coverage for Review:
  • Chapter 1 problems (solutions posted)
  • Click on Pre-Req Mat’ls - Euler’s Identity, EE3120 Review
  • Matlab quickstart tutorial, will be using Matlab starting Week 3.
  • Plan on initiating a survey to get a handle on your skill levels.
Prerequisite Material, Useful References (see course web page)

- Euler's Identity - The foundation of phasor analysis, as well as hyperbolic functions (used for long transmission lines)
- Basic Circuit Analysis, Thevenizing, Phasor Analysis, Impedance, P,Q,S, etc.: EE3120 pre-req practice problems | Solutions
- Basic 3-Phase Phasor Analysis - Review problem from EE3120
- Magnetic Circuits - quick review and introduction of how a transformer works
- Mutual Inductance - concept handout from EE3120 (refer to Section 2.2 of your text)
- Transformers 101 - Everything you wanted (or suddenly need to know) about transformers but were afraid to ask...
- Delta-Wye Transformer - detailed example with solution from EE3120
- EE 4221 Pre-Req Course Description
- EE 4222 Pre-Req Course Description
- Pre-Req Review Videos with Notes (from 2003 Archives)
  - Basic Circuit Analysis, Phasors, Three Phase Phasors: Lect 1 (skip first 12 mins) | Lect 1 Notes
  - Phasor Diagrams, Ideal Transformers, Nodal Analysis: Lect 2 (skip first 6:20) | Lect 2 Notes
  - Nodal Analysis, 3-phase circuits, Deltas and Wyes, Per Unit System: Lect 3 (skip first 3 mins) | Lect 3 Notes
  - Active & Passive Sign Convention for power flow, Per Unit, Transformers, Symmetrical Components: Lect 4 (skip first 2 mins) | Lect 4 Notes
  - Transformers, Induced Voltage & Polarity Marks, Phase Shift: Lect 5 (skip 3:45 - 5:20) | Lect 5 Notes
  - Phase Shift in Transformers, Phasor Diagrams, Application of Symmetrical Components: Lect 6 (skip first 3 mins) | Lect 6 Notes
  - Sample .m files from above tutorials: | for_ex.m | r2p.m | for_if_ex.m | while_ex.m | ft.m |
- Symmetrical Components - the basics.
Transformers -

Gen

\[ P_{\text{loss}} \propto i^2 R_{\text{line}} \]

\[ Z_c = \frac{300 \Omega}{2} \]

\[ \frac{n^2}{1} = \frac{50}{300} = \frac{1}{6} \]

\[ n^2 = \frac{1}{6} \Rightarrow n = \frac{1}{\sqrt{6}} \]
Non-Ideal

- Flux Leakage
- Winding Resistance
- Magnetic Saturation
- Core Losses < Eddy Currents
- Hysteresis
Laminations
\[ P_E = \frac{1}{t^2} \]

\[ 4\pi \times 10^{-7} \]

\[ \mu = \mu_r \mu_0 \]

\[ R = \frac{1}{\mu A c} \]
Lenz's Law

- Induced voltage causes a current, if coil is shorted, that produces a flux which cancels the $\frac{d\phi}{dt}$ that induced the voltage in first place.
\[ e_{\text{ind}} = N \frac{d\phi}{dt} = -\frac{di_2}{dt} \]

Faraday

Lenz
Mutual Inductance

\[ \frac{\frac{1}{L_2}}{\frac{1}{L_2} = \frac{1}{L_1} = \frac{1}{N_1}} \]

Self Inductance

\[ L_2 = N_2 \phi \]

Mutual Inductance

\[ \frac{\frac{1}{L_2}}{\frac{1}{L_2} = \frac{1}{L_1} = \frac{1}{N_1 \phi}} \]

Fundamental definition of inductance: \( L = \frac{\frac{1}{\phi}}{\frac{1}{N}} \)

- Section 4.4 in text, pp. 73-77.

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Inductance MUTUAL
How to Use the Concept of Mutual Inductance

Two-Port Device:

\[
\begin{bmatrix}
  i_1 \\
  i_2 \\
\end{bmatrix} = \begin{bmatrix}
  L_{11} & L_{12} \\
  L_{21} & L_{22} \\
\end{bmatrix} \begin{bmatrix}
  \frac{di_1}{dt} \\
  \frac{di_2}{dt} \\
\end{bmatrix} + \begin{bmatrix}
  V_1 \\
  V_2 \\
\end{bmatrix}
\]

Note: Reference direction of currents is into terminals at (+) side of voltage.

In time domain:

\[
\begin{bmatrix}
  V_1 \\
  V_2 \\
\end{bmatrix} = \begin{bmatrix}
  L_{11} & L_{12} \\
  L_{21} & L_{22} \\
\end{bmatrix} \begin{bmatrix}
  \frac{di_1}{dt} \\
  \frac{di_2}{dt} \\
\end{bmatrix}
\]

In phasor domain:

\[
\begin{bmatrix}
  V_1 \\
  V_2 \\
\end{bmatrix} = \begin{bmatrix}
  j\omega L_{11} & j\omega L_{12} \\
  j\omega L_{21} & j\omega L_{22} \\
\end{bmatrix} \begin{bmatrix}
  \tilde{I}_1 \\
  \tilde{I}_2 \\
\end{bmatrix}
\]

Also of note:

In some texts, since \( L_{12} \) and \( L_{21} \) are mutual inductances, they are called \( M_{12} \) and \( M_{21} \). Same thing.
Shell-form

Core form
Next: Ampere's Law
Next: **Ampere's Law**

\[ NI = \Phi R \]

**Electrical** / **Magnetic**

**MMF**
Ampere's Law

\[ NI = \Phi R \]

\[ \mathbf{H} = \frac{I_{\text{encl}}}{2\pi r} \]

\[ I_{\text{encl}} = \int \mathbf{H} \cdot d\mathbf{l} \]

I\text{Enclosed}

Clamp-on ammeter or current probe.