8/23/11

Class Intro

(Show website)

"Electronics for Scientific Instrumentation"

Similar to Introductory EE class

but Emphasize physics

Emphasize instruments and understanding

how they work

Lectures TTh 7:15 pm

Labs (some flexibility)

Grading

Lab Class \rightarrow Labs 45%

Final 20%

Midterms (2/3) 20%

HW 10%

(every week without HW)

Clickers 5%

\rightarrow Clickers - still working out bugs

Schedule - rough guide will adjust

Note: Blank Lecture Notes lecture slides
Textbook:
Bobrow: Fundamentals of EE 1996

all HW problems
detailed derivations
Lecture 1

What is Electronics?

Putting Maxwell's Equations to work

Continuity: \[ \mathbf{\nabla} \cdot \mathbf{D} = \frac{\partial \rho}{\partial t} \]

Faraday: \[ \mathbf{\nabla} \times \mathbf{E} = \frac{\partial \mathbf{B}}{\partial t} \]

Too complicated to be useful!
Think of rain on a hill

Useful when water collected into river

Linearization: \[ \mathbf{\nabla} \cdot \mathbf{D} = I \]

Contain B fields, \[ \frac{\partial \mathbf{B}}{\partial t} = 0 \]

in components

\( \mathbf{E} \cdot d\mathbf{r} \rightarrow V \)

Don't let charge build up

\[ \frac{\partial q}{\partial t} = 0 \]

Still have energy & motion

Charges moving \[ I = \frac{\text{coulombs}}{\text{sec}} = \text{Amp} \]

Potential energy \[ V = \frac{\text{Joules}}{\text{coulomb}} = \text{Volt} \]
Two intuition building analogies:

The Water Park

Height $\rightarrow$ Voltage $\quad V$ $\rightarrow$ wgh
Wires/Resistors $\rightarrow$ more channels
Channels $\rightarrow$ more current
less resistance

Tip a channel $\rightarrow$ more current

Ohm's law

Hydraulics

Water in pipes
very close analogy to electrons in wires

Electrons in wire $\rightarrow$ incompressible fluid

Wire $\rightarrow$ Pipe

Restriction $\leftrightarrow$ Resistor

Popp $\leftrightarrow$ Capacitor

Difference $\quad R_{\text{pipe}} = \frac{A}{R^4}$

$R_{\text{wire}} = \frac{A}{R^2}$

Resistor is a sand filled pipe!
Circuits & Components

Will usually be concerned with circuits: closed loops of wires & components

Open circuit

\[ V = IR \]

Linear

This is Ohm's Law

\[ I = \frac{V}{R} = \frac{E}{R} \]

Why don't electrons accelerate?

They bounce so have average velocity

"Sand" is appropriate
Another example:

Capacitor

\[ V = \frac{q}{C} = \frac{1}{2} \int I \, dt \]

\[ I = C \frac{dV}{dt} \]

also linear (but not static)

Note no net \( q \) builds up

Sources

\[ i = I \] (\( V \) doesn’t matter)

Faraday:

\[ \oint \mathbf{E} \cdot d\mathbf{r} = -\frac{d\Phi_B}{dt} = 0 \]

\[ \sum V = 0 \] KVL

\[ \sum I = 0 \] KCL

Continuity:

\[ \oint \mathbf{J} \cdot ds = -\frac{d\Phi_B}{dt} = 0 \]
Using KCL & KVL to combine resistors

Resistors in series

\[ R_{eq} = R_1 + R_2 \]

Proof:

\[ V_{ab} = i_1 R_1 \]
\[ V_{bc} = i_2 R_2 \]

\[ KVL: V_{ab} + V_{ba} + V_a = 0 \]
\[ KCL: i_1 = i_2 = \frac{V}{I} \]

\[ IR_1 + IR_2 = V = 0 \]
\[ I(R_1 + R_2) = V \]

Resistors in parallel

\[ R_{eq} = \frac{R_1 R_2}{R_1 + R_2} \]

Conductors in parallel

\[ C_{eq} = C_1 + C_2 \]

\[ G_i = \frac{1}{R_i} \]
Question: Important to be able to estimate on the fly.

1. \[ \frac{1 \Omega}{1 \Omega} \]

\[ R_{eq} = ? \]

(2 Ω)

2. \[ \frac{1 \Omega}{1 \Omega} \]

\[ \frac{10 \Omega}{10 \Omega} \]

\[ R_{eq} = ? \]

(100 Ω)
General Method to Analyze Circuits

KVL & KCL method 2N equations for N components

Node Method

1. Pick reference node, the "Ground Node".
   Ground should be the most connected node.

2. Label i's & V's \( V \text{ at node!} \) (w.r.t. ground)

3. Apply KCL at each node other than ground.

4. Replace I's with V's using component relations.

5. Solve set of equations.
\[ i_V + i_I - i_1 - i_4 = 0 \Rightarrow V_A = V_0 \]
\[ i_1 - i_2 - i_3 = 0 \]
\[ i_4 + i_3 - i_5 = 0 \]
\[
\frac{V - V_B}{R_1} - \frac{V_B}{R_2} - \frac{V_B - V_C}{R_3} = 0 \quad + \left( \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \right) V_B - \frac{V_C}{R_3} = \frac{V}{R_1} \]
\[
\frac{V - V_C}{R_4} + \frac{V_B - V_C}{R_3} - \frac{V_C}{R_5} = 0 \quad - \left( \frac{1}{R_3} \right) V_B + \left( \frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R_5} \right) V_C = \frac{V}{R_4} \]

\[
\begin{pmatrix}
\frac{1}{R_1} \cdot G_1 + G_2 + G_3 - G_3 \\
- G_3 \\
\end{pmatrix}
\begin{pmatrix}
V_B \\
V_C \\
\end{pmatrix}
= 
\begin{pmatrix}
G_1 \\
G_4 \\
\end{pmatrix}
\]

\[
\begin{pmatrix}
V_B \\
V_C \\
\end{pmatrix}
= 
\begin{pmatrix}
G_3 + G_4 + G_5 \\
G_3 \\
\end{pmatrix}
\begin{pmatrix}
G_1 \\
G_4 \\
\end{pmatrix}
\frac{V}{(G_1 + G_2 + G_3 + G_4 + G_5 + G_3^2)}
\]

\[ V_B = \frac{G_1 (G_3 + G_4 + G_5) + G_3 G_4}{(G_1 + G_3)(G_3 G_4) + G_3^2} \cdot V \]
Case \( R_1 = R_2 = R_3 = R_4 = R_5 = 1 \) \( \Omega \)

\[
\begin{pmatrix}
V_b \\
V_c
\end{pmatrix} = \begin{pmatrix}
3 & 1 \\
1 & 3
\end{pmatrix} \begin{pmatrix}
1 \\
1
\end{pmatrix} \frac{V}{8}
\]

\[V_B = V_2 = \frac{V}{2}\]

\[R_1 = R_5 = 2 \frac{1}{2} \Omega \quad R_2 = R_3 = R_4 = 1 \Omega\]

\[|G| = \begin{vmatrix}
4 & -1 \\
-1 & 4
\end{vmatrix} = 16 - 1 = 15
\]

\[
\begin{pmatrix}
V_b \\
V_c
\end{pmatrix} = \begin{pmatrix}
4 & 1 \\
1 & 4
\end{pmatrix} \frac{V}{15}
\]

\[V_B = \frac{3}{5} V\]

\[V_c = \frac{2}{5} V\]