EEP592 – **Applied Electromagnetics: How the Force of Maxwell's Equations Drives Circuit Theory and the Rest of Life -- Evan Goldstein**

Broad Course Aims:

1. To make clear how the world fundamentally works, by making crystal-clear the nature of the force that drives virtually everything-- the electromagnetic force.
2. In the process, to make clear how electrical engineering fundamentally works.

In the Process, You Will Also Learn:

1. How circuit-theory really works.
2. Why Kirchhoff's Voltage and Current Laws are accurate for a broad range of systems.
3. Why Kirchhoff's Voltage and Current Laws shatter in large systems at high frequency.
4. What exactly the basic electronic quantities of voltage, inductance, etc., actually are.

Basic Course Approach:

All the above follows from four little statements about the world: Maxwell's Equations. We will achieve formal clarity about them. But we push especially for sharp, gut-level intuition about what each equation says about the world.
That's the source from which profound understanding comes.

Course Prerequisites:

1. A clear understanding of the meanings of the derivative and integral of an ordinary single-variable function.
2. An interest in being quickly reminded of how phasor analysis works if you forgot (we'll extensively use it).
3. We'll also make solid use of vector calculus-- gradient, divergence, and curl. You need not know vector calculus in advance of the course (I'll teach you the elements in one week). But you do need to have an interest in learning or being reminded of its elements, including its three fundamental theorems.
4. A solid interest in how the world, and EE, work at a fundamental level.

What you need to do if you take this class:

1. Attend class (The course is at the board. No Powerpoint, class notes, or required textbook.)
2. Do weekly homework. (No labs. No projects.)
3. Take a quiz, midterm, and final.

Instructor: Evan Goldstein https://people.ece.uw.edu/goldstein_evan/

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Evan Goldstein

This is arguably the most fundamental course you'll ever take, if you take it

It asks just two questions:

1. How does the world fundamentally work?
2. How does electrical engineering fundamentally work?

It answers both questions with genuinely shocking clarity in 10 weeks.

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1. How does the world fundamentally work?

I.e.: What force drives the part of the universe that we inhabit?

2. How does EE fundamentally work?

- What are the primal, inviolable, bedrock laws at its foundation?
- Why are they true?

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The answer to both questions: THE ELECTROMAGNETIC FORCE

Fact: The electromagnetic force is, up to quantization, **completely** described by:

Maxwell's Equations

$$\nabla \cdot \mathbf{E} = \frac{\rho}{\varepsilon_0}$$

$$\nabla \cdot \mathbf{B} = 0$$

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$

$$\nabla \times \mathbf{B} = \mu_0 \mathbf{J} + \mu_0 \varepsilon_0 \frac{\partial \mathbf{E}}{\partial t}$$

➡ **To grasp how EE and the world work, must grasp Maxwell's Equations**

How to do that?

Must be crystal-clear about the formal and intuitive meanings of:

① The fields, $\mathbf{E}$ and $\mathbf{B}$

② The vector-calculus operations of divergence and curl

I.e.: Must be crystal-clear about structure of the universe's dominant force interaction, as asserted by Maxwell's Equations

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Are you serious? That's a ridiculous amount of work.
So what would I get from this course if I did all of that?

- A crystal-clear understanding of the **force that drives the universe**
- A sharp grasp of EE's foundations– of **why circuit theory, KVL, KCL work**
- An understanding of **circuit theory's limits**– of where it all shatters
- And as a byproduct, *finally,* a command of *exactly* what the fundamental EE quantities of **voltage**, **inductance**, and **capacitance** *are*

Really? I never learned any of that stuff. Isn't this largely of theoretical interest?

For most of the history of EE: Yes. It was.
That era's history. These limits are now crucial in high-speed systems, where:

- High operating frequencies
- Large physical size of cutting-edge circuits

Circuit theory is now careening into fundamental limits and is shattering

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You said I'd have to know exactly what divergence, curl, and all that stuff is. I don't. So do I need to know vector calculus before taking this class?

No. But you need to want to learn the elements of it. I'll teach you those in a week. (What you do need: solid grasp of meaning of derivative and integral of an ordinary function *f(x)*).

This class looks killer hard. Is it?

No. It's killer illuminating. For those thirsty to see deep into life and EE, it's thrilling. But there's no denying: it's 10 weeks of solid work.

Ok. Class looks horrible. So just checking: what would I need to do if I took it?

No extraneous stuff. (No labs, no projects, no presentations, no extra credit)

Instead:

Attend class (There are no class notes, no Powerpoint, no required textbook).
Weekly homework.
Quiz. Midterm. Final.

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