8.02 ESG Independent Study

Unit 14: AC Circuits

In previous units, we have seen that electric and magnetic fields have associated with them energy densities, so that the fields themselves are dynamic quantities. Electric fields arise from charges, magnetic fields arise from currents, and since current represents movement of charge, it should not be surprising that changes of electric fields are related to changes in magnetic fields. Faraday's Law (introduced in unit 11) states this explicitly in terms of changing magnetic flux, and Ampère's Law can and will (unit 15) be re-expressed to account for changing electric flux (due, of course, to moving charges). This unit will investigate the ways in which electric and magnetic energies oscillate in certain special circumstances. In applications to electric circuits, which in general have resistances which dissipate energy, we'll consider cases where energy is introduced via a sinusoidal voltage (your basic generic AC circuit).

The applicability of AC circuits need not be emphasized here; the fundamental influence of electric toothbrushes on civilization has been well documented elsewhere. This unit will look at how these omnipresent oscillations can be understood as manifestations of basic electric and magnetic properties of circuit components.

Application of Kirchoff's Laws to an AC circuit reduces the physics to a mathematical analysis, and there are many routes from which to choose in approaching such a beast. The most complete method, which can include coupled oscillators, transients, and anharmonic inhomogeneous terms (don't ask) involves more mathematical treatment than is usually needed in 8.02 (we're talking serious 18.03, at least). Purcell's treatment uses complex exponentials, a technique that, once mastered, yields simple results from complicated situations. University Physics and Sears, Zemansky & Young use phasors, a method which relies on a geometric analog of oscillatory motion. Marion & Hornyak uses a pleasant compromise.

In any event, the mathematical technique employed can't change the physics; inductors induct, resistors resist, capacitors capacit, and electric toothbrushes brush.

Objectives: Upon completion of this unit, you should understand why a system with capacitance and inductance exhibits oscillatory behaviour and be able to predict the response of a simple circuit to an oscillatory applied voltage.

Suggested Procedure:

1. Read UP11 sections 30.4 throught 30.6 and all of chapter 31. Suggested problems from chapter 30 are 19, 27, 29, 35, 71, 78 and from chapter 31 are 6, 12, 13, 14, 23, 31, 33, 38, 62 (every E
M student has to do this one), 69 (mostly algebra and 18.01-type stuff).

   or,

2. Read chapter 8 in Purcell. Section 8.2 compresses a lot of math into a few equations, so be sure you understand the steps in the derivations. Complex exponentials are introduced in section 8.3 and phasors are used in section 8.4. If you don't fall in love with complex exponentials at first sight, look at Feynman Volume I, section 22–5&6 and chapter 23. Suggested problems from Purcell include (pp. 319–321) #s 4, 6, 7, 9, & 13.

3. Take a unit test.