8.02 ESG Independent Study

Unit 16: Electromagnetic Waves and Light

The development of Ampère's Law with the inclusion of the term involving changing electric flux strongly suggests that Maxwell's equations admit non-trivial solutions in the absence of currents or charges. This final unit examines certain of these solutions and explains how we find not only oscillatory solutions but propogating solutions. By propagation we mean that we can exhibit electric and magnetic fields which are consistent with Maxwell's equations such that in certain regions of space the energy density associated with the fields enters one side of the region, passes through, and leaves the region, with the direction of propagation predictable from the field configuration.

Very well, these are solutions of a set of coupled partial differential equations, but do they (the fields, not the equations) exist? You bet! In fact, the predicted speed of propagation of these waves was seen to be that of light; indeed, light is a form of electromagnetic radiation.

In this unit, we will show that components of the fields in free space satisfy the *wave equation.* a partial differential equation with solutions which are well known and are known to represent propagation with a fixed speed. For longitudinal waves such as sound, this speed is measured with respect to still air. For transverse waves such as waves along a stretched string, this speed is measured with respect to the direction perpendicular to the string's motion. For more complicated motion, such as water waves, the speed is again measured with respect to still water.

So, when Maxwell's equations in free space give us "a speed of light", that's with respect to what? We're in *free space.* By now you may have guessed; different observers moving *relative* (get it?) to each other may see different fields, but the speed of propagation of these fields will be independent of the speed of the observer, and we get all of this from Maxwell's equations.

As may be expected, Purcell treats the relativistic aspects of E&M in more depth than UP. Also, regardless of frame, electromagnetic waves have to come from somewhere, and Purcell treats sources of radiation in more detail.

Objectives: After completing this unit, you should be able to obtain wave solutions from Maxwell's equations, identify characteristics of sinusoidal waves and explain how to determine the flow of energy associated with electromagnetic waves.

Suggested Procedure:

1. Read chapters 32 and 33 in UP11 (What is wrong with Figure 33-29?). Suggested problems from chapter 32 include 8, 21, 30, 34, 43ab, 44, 49, 54 and from chapter 33 include Q3, Q4, 12, 16, 22, 24, 40, 32, 52, 53 (these last two really are a pair).

   or,

2. Read chapter 9 in Purcell, sections 4–7 and appendix B (you might want to review the appropriate parts of chapter 5 and appendix A). Also, read or reread section 6.7. Suggested problems include (pp. 343–354) #s 5, 7, 12, 13, and (pp. 462–463) #s 1 & 2. #4 is optional but recommended for those interested in high energy particle or plasma physics. Purcell does not deal with the Poynting vector explicitly, although he does refer to S as a "power density". The vector $\vec{S}$, in CGS units, is $\vec{S} = \frac{c}{4\pi}\vec{E} \times \vec{B}$. The above problems (from chapter 41 in H&R) #s 26, 31 & 32 deal with explicit uses of $\vec{S}$.

3. Take a unit test.