Physics 4220H Fall 2012: Learning Outcomes

By the end of the course, students are expected to be able to...

1. write down, from "memory", Maxwell's Equations in differential form, both in vacuum and in (linear) media.
2. show how the continuity equation—an expression of charge conservation—is implicit in Maxwell's Equations.
3. compare the continuity equation and Poynting's Theorem in terms of conservation laws, and argue, by analogy, that the Poynting vector is an "energy density current" of sorts.
4. describe electromagnetic fields in linear media, including the presence of "displacement currents", displacement field, **D**, and magnetic field **H**; and how they differ from fields **E** and **B**.
5. describe mathematically the energy density and total energy stored in electromagnetic fields, as well as the *flow* of energy.
6. write down, from "memory"—or better yet, derive—the (four) typical boundary conditions for the electric and magnetic field components parallel and perpendicular to an interface between linear media.
7. show how Maxwell's Equations suggest that electricity and magnetism are linked via the propagation of fields at the speed of light.
8. describe the procedure for using typical boundary conditions for electromagnetic fields to derive the Fresnel Equations for reflection and transmission in a dielectric interface in the case of incident-plane and orthogonal polarization.
9. Describe the presence or absence of "Brewster's angle" for reflection off a dielectric interface for transverse-E and transverse-B polarized light. Link this condition to the Fresnel Equations.
10. Generate the Transmission and Reflection coefficients from the Fresnel Equations, and sketch the transmitted and reflected power as a function of incident angle for transverse-E and transverse-B polarized light.
11. calculate/estimate reflection and transmission coefficients from the dielectric function of various materials.
12. describe how material (linear) conductivity can be included in Maxwell's Equations and how this inclusion subsequently leads to absorption.
13. apply boundary conditions to obtain reflection and transmission behaviour of metals and dielectrics.

14. describe the meaning of “skin depth” and use this parameter to calculate electromagnetic attenuation in media.
15. describe the relative phase differences between the electric and magnetic field oscillations in nonconductive and conductive media. Estimate the magnituded of this phase difference as a function of the “quality” of conductor through which the fields propagate.
16. relate the real and imaginary components of the index of refraction (n and k) to the dielectric function.
17. show (or at the very least, describe) how dispersion arises in the dielectric function.
18. describe quantitatively and qualitatively the dielectric function (ϵ) of conductors and insulators.
19. apply boundary conditions in waveguides and cavities to obtain “modes”; use the obtained dispersion relations of such modes to describe the frequency progression of allowed waveguide modes.
20. describe the presence or absence of cut-off frequencies in various devices such as square channel and coaxial waveguides.
21. calculate “skin-depth” or attenuation behaviour of electromagnetic radiation in a conductive channel as a function of frequency and “waveguide” size.
22. explain the need for re-parametrizing scalar and vector potentials in “retarded-time”.
23. work with “retarded-time” as a parameter; including the necessary vector algebra and calculus.
24. describe the differences, both fundamental and functional, between near- (or induction) fields and radiation fields.
25. describe quantitatively and qualitatively radiation from oscillating electric and magnetic dipoles.
26. describe at least one outstanding paradox of radiation from accelerating charges (for example, with respect to causality).
27. link the history of the atomic model with the concept of radiation from accelerating charges.