DEPARTMENT OF PHYSICS
PH 632 : ELECTROMAGNETIC FIELDS AND INTERACTIONS 2
WINTER 2002

(I) ***GENERAL INFORMATION*** :

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Office hours : Tue., Thurs. : 2:30 p.m. - 3:30 p.m., or by appointment

Course grade : Homework - two to three problem sets : 60%
Final exam (take home) : 40%
Project :

Text : (1) J. D. Jackson : " Classical Electrodynamics " , 3rd ed., (John Wiley & Sons, New York, 1998).

References : (2) L. D. Landau and E. M. Lifshitz (vol. 2) : " The Classical Theory of Fields " , 4th ed., (Pergamon, Oxford, 1975).
(3) L. D. Landau, E. M. Lifshitz and L. P. Pitaevskii (vol. 8) : " Electrodynamics of Continuous Media ", 2nd ed., (Pergamon, Oxford, 1984).

** *A very good, interesting and elementary reference for electromagnetic waves and radiation* :
G. Bekefi and A. H. Barrett : " Electromagnetic vibrations, waves, and radiation ", (MIT, Cambridge, 1977).

Overview of the whole sequence of the three courses :
This sequence (PH 631, 632, 633) deals mainly with an advanced study of classical electrodynamics at the graduate level. This involves principally the formulation and application (solution) of the full set of Maxwell equations (ME), together with the study of the fundamental properties such as symmetry of this set of equations. Since in the most general situation ME contains a set of time-varying vectorial coupled partial differential equations, the solution of which can become extremely complicated. Furthermore, the constitutive relations required for the complete specification of the set of ME may be in general highly nontrivial for an arbitrary dielectric medium, one can expect the solution of electrodynamics problems involving dielectric medium can be tractable only for a few simple cases. We shall divide our study into the three quarter courses as follows :

PH 631 : **Electrostatics and Magnetostatics**
This course will deal away with all the time-varying terms in ME, i.e., situations will be limited to charges at rest (electrostatics) or in uniform motion giving rise to a steady current (magnetostatics). Both vacuum and dielectric media will be considered. Students will learn various techniques of solving statics problems in this course. The content follows closely Jackson's book (Chs. 1,2,3,4,5). For problems involving dielectric media, references will also be made to the first 4 chapters of the book by Landau et al (vol. 8); especially the worked examples found in these four chapters.

PH 632 : **Electrodynamics : Electromagnetic Waves and Radiation**
This course will explore the formulation and implication of the full set of time-varying ME, mainly in vacuum but also in dielectric media. Propagation and generation of various electromagnetic waves and radiation will be studied. Again, Jackson's book (Chs. 6,7,9,14) will be followed closely. Details will be given later in the Winter quarter.

PH 633 : **Special Topics**
These include topics like waveguides (Jackson, Ch.8); Application of EM theory to optics (Jackson, Ch. 10); Relativistic covariant formulation of electrodynamics (Jackson, Chs.11,12; Landau et al (vol. 2) (Chs.3,4)); Radiation and energy loss from

charged particles in non-uniform motions (Jackson, Ch.13,15,16); Numerical methods in solving EM problems (Jackson, Sec. 1.12, 1.13, 2.12, 5.14, ...). Topics will be selected and re-ordered from the above list depending on the time available. Details will be given later in the Spring term.

Mathematical background : This is one of the most mathematically involved graduate courses. Background knowledge in techniques such as: Fourier transform; Complex analysis; Green function; Theory of special functions with regard to the solution of partial differential equations;...etc. will be very useful. Many of these will be taught along with the progress of the course, but it will be helpful if students have had a little experience with some of them prior to taking this course.

(II) COURSE OUTLINE (PH 632) :

Unit 6 : Magnetostatics *(Topic left over from PH 631)*

Condition for steady electric current; the laws of Biot-Savart and Ampere; concept and multipole expansion of the vector potential; concept of magnetic induction (B) vs magnetic field (H); boundary conditions for B and H, and general treatment of magnetostatics problems as boundary value problems. (J : 5.1-5.6)

Unit 7 : Electrodynamics : The full set of Maxwell equations (ME)

Faraday's law; Maxwell's displacement current; formulation of the four ME; conversion between Gaussian and MKS (SI) unit systems; potential formulation; gauge transformations; electromagnetic wave equation and its Green function solution; retarded and advanced solutions; symmetry of ME with respect to spatial and temporal transformations; possible future modifications for the set of ME (e.g., to admit the existence of magnetic monopoles and finite photon mass). (J : 6.1-6.6, 6.11-6.13; L&L v.8 : sec. 75, 76; L&L v.2 : sec. 26-30)

Unit 8 : Energy-momentum of electromagnetic (EM) fields and sources

Poynting's theorem and conservation of energy-momentum for fields and sources; brief discussion of the tensorial formalism and energy-momentum in a dielectric medium; comments on dispersive and dissipative medium. (J : 6.8-6.10; L&L v.8 : sec. 77, 79-82; L&L v.2 : sec. 31-35)

Unit 9 : Propagation of (EM) waves

Plane waves in homogeneous media including both nondispersive and dispersive media as well as nondissipative (dielectric) and dissipative (conducting) media; propagation crossing boundaries of multilayer systems; polarization, reflection and transmission of plane waves; Fresnel equations and matrix formulation; Kramers-Kronig relation for dissipative medium; brief discussion on spherical waves. (J : 7.1-7.11; L&L v.8 : sec. 77-89; L&L v.2 : sec. 46-52)

Unit 10 : EM radiation : simple radiating systems and general treatment

The three mathematical treatments of radiation problems (expansions in potentials; expansions in fields; and the Hertz vector approach); systematic derivation of multipole radiation (E1, M1, E2, etc.); calculation of time-averaged radiated power (angularly distributed & total power) for simple localized radiating systems. (J : 9.1-9.5; 16.1-16.8; L&L v.2 : sec. 62,66,67,71,72)

Unit 11 : Radiation by moving charges *(will be left for PH 633 if time is not sufficient)*

Lienard-Wiechert potentials and fields for a point charge; radiation from nonrelativistic accelerating charged particles (Larmor's formula) and generalization for relativistic moving particles; angular and total radiation power; different types of radiation from accelerating particles (in both linear and circular motions) : bremsstrahlung, cyclotron and synchrotron radiation, transition radiation. (J : 14.1-14.6, 14.9; L&L v.2 : 63,64,68-70,73,74,77)

Unit 12 : Other optical phenomena *(probably to be left for PH 633)*

Scattering of EM waves by various targets (e.g. Thomson scattering, Rayleigh scattering, Mie scattering, etc.); diffraction phenomenon (scalar theory, vector theory, Babinet's principle, small aperture diffraction, etc.). (J : 9.6-9.14, 14.7,14.8; L&L v.8 : sec. 92-95; v.2 : sec. 53-61,78-80)