PHYSICS 513-515

For 513-515 the text is Jackson, 3rd edition. For the parts of 513 concerned with mathematical methods the texts are Dennery & Kryzwicki (90's edition) and Arfken & Weber.

PHYSICS 513:

Review of electrostatics, and magnetostatics. Maxwell's equations; vector & scalar potentials. Other equations of mathematical physics. Complex variables for physics applications. Green's functions and boundary value problems. Multipole moments, electrostatics of macroscopic media

Goals of course:

Review of undergrad E & M. Advanced ideas and solving complicated problems in E & M. Introduction of mathematical methods for other courses & research and bringing your use of math in physics to a professional level. Preparation for qualifying exam. Discussion of some modern physics topics.

List of topics:
Introduction

Reasons for studying E&M in thte twenty-first century; Review Coulomb's law; Dirac delta function; Gauss law, Poisson's eq.; Laplace equation; electrostatic potential

Review Magnetism Ampere's law, magnetic dipoles, Faraday's law, Maxwell's term write Maxwell's equations, general solution in terms of Φ, A

Radiation field E, B ~ 1/r, angular distribution of radiated power, radiation in the electric dipole approximation

Boundary value problems for Laplace and Helmholtz equations Image charges and Green's functions (static and non-static); Two dimensional boundary condition problems as introduction to complex variables;
Complex variables Dennery and Kryzwicki -best text, 90's edition has misprints corrected Complex numbers, complex functions, differentiation and analyticity multi-valued functions-logarithm Complex potential and conformal mapping for solving boundary value problems Integration techniques-Cauchy's theorems Taylor series, Laurent series, calculus of residues (Helmholtz Green's function as an example), Riemann surface, analytic continuation integration again -Saddle point methods method of steepest descent,
Back to physics
Solution of Laplace (also Helmholtz) equation in 3 dimensions spherical coordinates, scalar potentials with azimuthal symmetry, Sturn-Liouville theory, Spherical harmonics, Green's function in spherical coordinates, Multipole expansion for static electricity, energy of system in external field

514 Syllabus

Physics of dielectrics-$\vec{E}$ vs. $\vec{D}$; Physics of magnetic materials-$\vec{B}$ vs. $\vec{E}$; Macroscopic version of Maxwell's equations; Symmetries of the electromagnetic field; magnetic monopoles; Electromagnetic waves in free space, dielectrics, conductors and plasmas; Wave guides

Detailed list of topics

Dielectric materials D vs E, boundary conditions and boundary value problems, energy of system

Magnetic materials H vs B, boundary conditions and boundary value problems, magnetic energy

Conservation of 4-momentum for charges and currents Poynting vector energy momentum tensor

Symmetries-rotation parity time reversal

Magnetic monopoles meaning, experimental search Dirac's monopole, charge quantization

Electromagnetic waves propagation, polarization, boundary value problems, waves in a conducting medium, frequency dependence of □ and □, including classical and quantum ideas for computing these. How can speed of light in material be very slow

Causality Kramers Kroneg dispersion relations, limits on the speed of light, superluminal propagation doesn't violate causality

wave guides

PHYSICS 515

Overview The aim is for students to apply the mathematical and physical background developed in 513 and 514 towards understanding problems of relevance to astro-, atomic, condensed matter, nuclear and particle physics. We begin with wave guides and resonance cavities, and use the MIT bag model of elementary particle physics as an example. Then the theory of radiation, developed earlier, will be extended to include the full multipole expansion. Scattering and diffraction, with examples from sound wave phenomena will be covered next. The special theory of relativity will be reviewed and the Maxwell equations cast in a covariant form to enable us to transform $\vec{E}$ and $\vec{B}$ between different inertial reference frames. Relativistic particle dynamics will then be discussed. We also hope to discuss the features of collisions between charged particles, and radiation by relativistically moving charges that are most relevant for condensed matter and elementary particle physics.

List of topics

Wave guides & resonant cavities use of rectangular, cylindrical (Bessel functions), and spherical coordinates, perfect conductors first then brief imperfect conductors MIT bag model as a resonant cavity and solution of Helmholtz equation (spherical Bessel functions)

radiation magnetic dipole radiation(neutron star), quadrupole radiation; General multipole expansion for radiation; selection rules for radiative transitions

Scattering of long wavelength light: Thompson scattering and polarization phenomena

Scalar diffraction theory, Frauenhofer diffraction

Relativity postulate of relativity, Lorentz transformation from speed of light is the same in all inertial reference frames, addition of of velocity, space time as a four vector Proper velocity four vector, Momentum-energy conservation in reactions-mass to energy eg pp pppp¯p¯, Light cone, proper time, Four vectors, tensors contravariant and covariant, Covariance of Maxwell eqns, transforming E & B, relativistic Motion in uniform E,B fields and combinations,

Advanced topics Lienard-Wiechert potentials; Cerenkov effect; radiation-total power, angular distribution for relativistic charged particles, Distribution frequency and angle of energy radiated,

If time permits– Bremsstrahlung, Radiation damping.