List of problems/topics from 442 – Summer 2025

1. Ch 7 review
    a. How to find E for a changing B (the "Faraday current")
    b. How to find B for a changing E (the "displacement current")
2. Ch 7 new
    a. How to use polarization current and other currents to derive Ampere's law for H
    b. How to apply the scattering model to obtain and use Ohm's law
    c. How to find inductance and mutual inductance for a given geometry
    d. How to calculate energy stored in fields/work done to assemble charges & currents
3. Ch 8
    a. How to use the Poynting vector to calculate energy flow
    b. How to understand work and energy using Poynting's theorem
    c. How to calculate the momentum stored in the fields
    d. How to use the Maxwell Stress Tensor theorem to calculate force on a charged object
    e. How to express and understand conservation laws as continuity equations: charge, energy, and momentum
4. Ch 9 part 1
    a. How to derive and apply wave differential equation (1d and 3d)
    b. How to calculate reflected and transmitted amplitudes and powers for waves on ropes
    c. How to represent plane waves as complex exponentials, understanding what all of the terms are and how they relate to each other (e.g. complex amplitude, wavevector, position, angular frequency, time, polarization vector, wavelength, frequency, wave speed, index of refraction, ε_r)
    d. How to use the Poynting vector to calculate the intensity of a plane wave
    e. How to use the Fresnel equations calculate reflected and transmitted amplitudes and powers for light waves (including both s- and p-polarizations, and special situations such as Brewster's angle and total internal reflection)
5. Ch 9 part 2
    a. How to adapt all of the relevant equations for situations in which one has a complex wavevector, a complex index of refraction, and a complex ε_r
    b. How to relate the conductivity of a conductor to those complex quantities
    c. How to calculate the skin depth of a conductor
    d. How to describe conductors in the three typical limiting cases
    e. How to apply the results of the Lorentz model to both insulators and conductors, in both the optical and other frequency regimes
    f. How to describe and understand waveguide modes, including TE and TM modes and their associated boundary conditions
    g. How to use the dispersion relation for rectangular and cylindrical waveguides
6. Ch 10
    a. How to find electric and magnetic fields from the scalar and vector potentials
    b. How to apply a gauge transformation to obtain a new set of potentials
    c. How to derive the inhomogeneous wave equations for V and $\mathbf{A}$ from the Lorenz gauge condition
    d. How to use retarded time to solve for V and $\mathbf{A}$ given charge and current densities changing in time.
    e. How to understand Jefimenko's equations at a conceptual level
    f. How to derive and use the Lienard-Wiechert potentials of moving point charges
    g. How to calculate the electric and magnetic fields of a moving point charge, including using the constant velocity simplification as appropriate.
7. Ch 11

    a. How to calculate electric dipole radiation, including its angular dependence
    b. How to calculate magnetic dipole radiation, including its angular dependence
    c. How to calculate multipole radiation in general, at least for relatively simple situations
    d. How to use Larmor and Lienard formulas to calculate the radiation produced by a point charge, including for the specific cases of synchrotron and bremsstrahlung radiation
    e. How to use and conceptually understand the radiation reaction force (Abraham-Lorentz force)
8. Ch 12 part 1
    a. How to calculate basic relativistic quantities such as length contraction, time dilation, and the frame-to-frame velocity transformation (longitudinal and transverse)
    b. How to represent events & world-lines on space-time diagrams
    c. How to transform events, world lines, and other various quantities such as elapsed times and distances, to different reference frames
9. Ch 12 part 2
    a. How to use and transform various 4-vectors: 4-velocity, 4-acceleration, 4-force, 4-momentum, 4-vector potential, 4-current density
    b. How to construct and use relativistic scalars from the 4-vectors
    c. How to solve problems using conservation of relativistic energy and momentum
    d. How to calculate the transformed electric and magnetic fields in different reference frames
    e. How to represent and transform fields using the field tensor and the dual tensor
    f. How to use relativistic tensor notation to write foundational equations from 441 and 442