Physics 462: EM Waves and Optical Physics

Recommendations for review/study:

- Review the class notes and reading. Work through any derivations or examples that are unclear to you.
- Review the homework solutions, even for problems you got credit for. Often it helps to see other (possibly shorter) ways to do a problem. I will often base a test question on a homework problem.

Basic math literacy

- working with complex numbers: extracting amplitude and phase, taking abs values, conjugation, representing sines and cosines as exponentials.
- representation of waves with real functions(sine, cosine) and with complex exponentials. Amplitude, phase, frequency, wavenumbers, phase velocity.
- Taylor expansion: especially 1st order small angle expansion of sin, cos, $(1+\varepsilon)^n \approx 1+n\varepsilon$.

For first Midterm:

Maxwell equations

- integral form of Maxwell equations: generally for charges and currents
- electric and magnetic flux integrals, Gauss' law
- continuity equation for charge/current
- scalar and vector potentials: gauge invariance
- energy density and energy flow (Poynting vector), stress-energy tensor

Basic EM wave propagation

- 3-D k-vector, 3-D plane waves, **k**, **E**, **B** are mutually perpendicular for plane waves
- Derivation of wave equation in free space from Maxwell equations
- Calculation of irradiance (intensity), energy density and Poynting vector from the fields
- Cycle averaging to get at mean values of irradiance.
- Using Maxwell curl equations (Faraday and Ampere laws) to get **B** from **E** and vice versa.
- Phase and group velocity calculation: calculate vg = $(dk/d\omega)^{-1}$; calculate v_g as a function of index.
- Momentum and pressure in fields

Polarization

- polarization states: linear, circular and elliptical
- representing polarized waves with complex exponential notation with Cartesian vector components
- representing polarization states using either linearly-polarized or circularly-polarized basis states
- optical activity: refractive index depends on R or L circ polarization
- representing polarization states with Jones vector notation
- transformation of polarization states with propagation through birefringent media (waveplates) and through phase changes from Fresnel reflection
- using Jones matrices and rotation matrices to compute changes in polarization states

EM waves at boundaries

- In a region of constant index n, components of wave vector are related by: $\sqrt{k_x^2 + k_y^2 + k_z^2} = nk_0 = n\omega / c$. For plane waves, forward propagation phase is continuous along boundary.
- Boundary conditions for normal and tangential components of the E- and B-fields:
  - Dielectrics: all are continuous for nonmagnetic materials except for the normal component of the E-field
- Reflection from an interface: treat the two polarization directions separately, it is usually easier to solve for the fields that are continuous across the boundary
- Derivation of Snell's law in different ways: phase continuity, Fermat's principle of least time
- Using the Fresnel coefficients as amplitude and phase factors on reflected, transmitted waves.