PHYS306 Homework#4 (Due on 17Mar2022)

Q#1:

(a) Suppose some free charge is embedded in a piece of glass. About how long would it take for the charge to flow to the surface?
(b) Suppose you were designing a microwave experiment to operate at a frequency of 10^{10} Hz. How thick should be the coating of silver metal to shield the microwaves from exiting the oven.
(c) Find the wavelength and propagation speed in copper for radio waves at 1 MHz. Compare the corresponding values in air (or vacuum).

Q#2:

(a) Calculate (time averaged) energy density of an electromagnetic plane wave in a conducting medium. Show that the magnetic contribution always dominates.
(b) Find a relationship of intensity in a conducting medium as a function of the amplitude of electric field and distance z in the medium.

Q#3:

Calculate the reflection coefficient for light at an air-to-silver interface (consider $\mu_1 = \mu_2 = \mu_o$ and $\epsilon_1 = \epsilon_o$ and $\sigma = 6 \times 10^7\ (\Omega.m)^{-1}$) at optical frequencies ($\omega = 4 \times 10^{15}/s$)

Q#4:

(a) Find the width of the anomalous dispersion region for the case of a single resonance at frequency ω_o. Assume $\gamma \gg \omega_o$.
(b) Show that the index of refraction assumes its maximum and minimum values at points where the absorption coefficient is at half-maximum.
(c) Assuming the negligible damping ($\gamma_j = 0$), calculate the group velocity the waves described by the following equations:

$$\tilde{E}(z,t) = \tilde{E}_o e^{-\kappa z} e^{i(kz-\omega t)} \text{ and where } \tilde{k} = k + i\kappa = \frac{\omega}{c}\left[1 + \frac{Nq^2}{2m\epsilon_o}\sum_j \frac{f_j}{\omega_j^2 - \omega^2 - i\gamma_j\omega}\right]$$

Q#5:

(a) Consider a rectangular waveguide with dimensions 2.28cm x 1.01cm. What TE modes will propagate in this waveguide, if the driving frequency is 1.7×10^{10} Hz?
(b) Suppose you wanted to excite only one TE mode; what range of frequencies could you use? What are the corresponding wavelengths (in open space).

Q#6:

(a) Confirm that the energy in the TE_{mn} mode travels at the group velocity.
(b) Work out the theory of TM modes for a rectangular waveguide. In particular find the longitudinal electric field, the cutoff frequencies and the wave and group velocities. Find the ratio of the lowest TM cutoff frequency to the lowest TE cutoff frequency, for a given waveguide.