Optical Properties Exam Question #1: Lorentz Oscillator Model (10 pts)

In the Lorentz Oscillator Model, we consider the motion of a charged particle bound to a fixed core of opposite charge.

a) (2pts)Draw the frequency dependent response of a single negatively changed particle (with a single resonant frequency) to an applied harmonically oscillating driving field. You are welcome to draw either ε or χ. Draw the real and imaginary parts separately. (3pts)

b) (2pts) Consider a material with a single resonance at 3μm (near infrared). Based on the graphs you drew above, circle the correct statement below (n is the real portion of the index of refraction):

$n_{800nm} > n_{700nm,}$ $n_{800nm} < n_{700nm,}$ Can't tell

c) (4pts) Draw the corresponding dielectric response for a free electron gas. Do so for both the situation of no damping and the case with damping. The precise details of the drawing can be left vague, but the general response should be evident

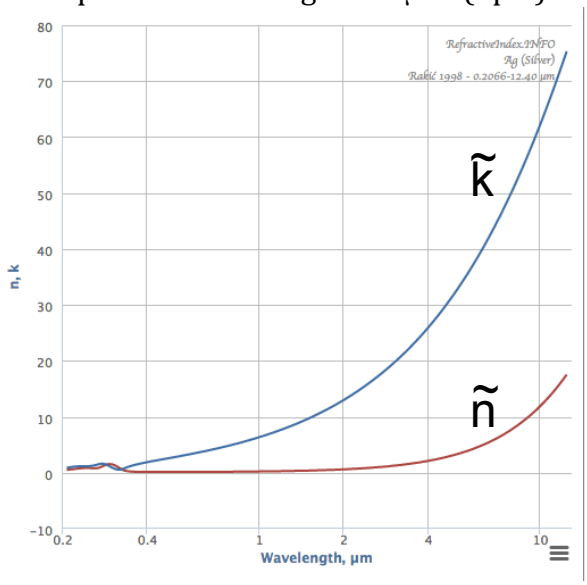
d) (2pts)For a metal modeled with a free electron response, predict the normal incidence reflectivity for light at a frequency lower than the plasma resonance.

Optical Properties Exam Question #2: Absorption of Light in Materials (10pts)

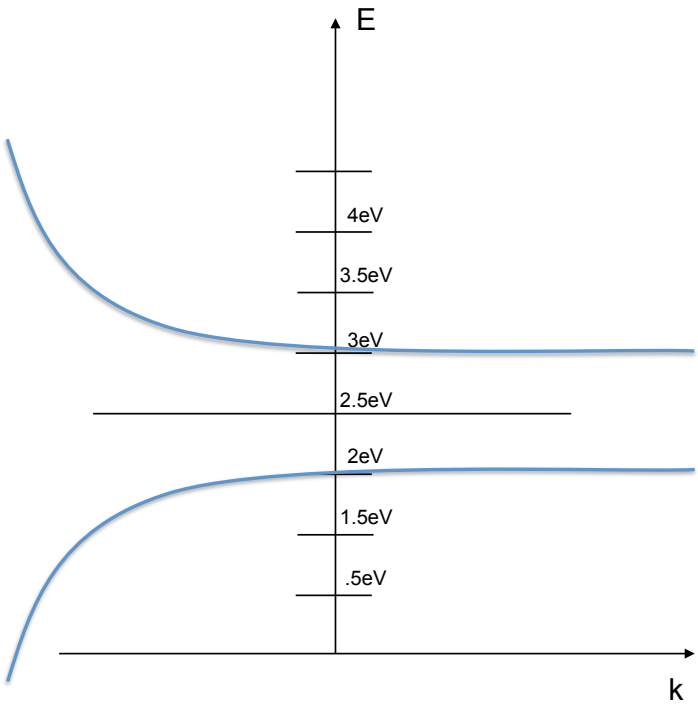
a) Starting from the equation for a wave propagating in a material $E = E_0 e^{i(kx-\omega t)}$, show that the inclusion of a complex component to the Index of Refraction leads to absorption (2pts).

b) Absorption of light occurs over a lengthscale called the *skin depth*, where the intensity falls off to 1/e from its initial value. From the expression you arrived at above, find the skin depth. (3pts)

c) Estimate the skin depth at a wavelength of 1μm. (3pts)



d) Consider the contrived band structure shown below (the 2.5eV line corresponds to the Fermi Energy) (2pts):



On this graph draw an interband transition with a photon of 1.5eV. Similarly, draw (all possible) interband transitions at 1eV.

Optical Properties Exam Question #3: Nonlinear Response (10pts)

a) Write the full expansion of material Polarization to include up to third order effects (1pt).

b) The polarization acts as a source term for the wave equation and leads to generation of new frequencies of light (the second harmonic in this case). Discuss in general terms how the intensity of generated light scales with the intensity of the input field. (2pts).

c) Correspondingly, how does the output intensity of a third harmonic generation process scale with input intensity? (2pt)