Problem Set 5 – Phys 4510 Optics – Fall 2014

Due date: Th, October 9, in class

Reading: Hecht 5.1-5.2

1. We would like to continue the discussion of the optics of metals as a follow up on problem 5 on the last homework sheet.

   We consider again Au and Ag in the Drude description of their dielectric function.

   The relevant parameters were given by:

   Au: $n = 5.9 \times 10^{28}$ m^{-3}, $\sigma = 4.9 \times 10^{7}$ Ωm^{-1}, $m^*/m_e = 0.99$, $\epsilon_\infty(Au) = 9.84$
   Ag: $n = 5.76 \times 10^{28}$ m^{-3}, $\sigma = 6.6 \times 10^{7}$ Ωm^{-1}, $m^*/m_e = 0.96$, $\epsilon_\infty(Ag) = 3.7$ Note: n is carrier density, not to be confused with real part of index of refraction for which we also used n by convention (but the difference should be clear from the context).

   a) You have already plotted the dielectric function Re(ϵ) and Im(ϵ) for Au and Ag in the energy range from 0.5 to 3.5 eV. Now derive expression and plot n and κ for the same energy range. Indicate in your graphs the location of the plasma frequency.

   b) Next we are interested in the conductivity σ. Convert ϵ into σ and plot the real and imaginary conductivity. How does your low frequency value of the real part of the conductivity compare to the DC conductivity? What optical cycle period T does the energy for the peak of imaginary part of the conductivity correspond? How does that value compare to the Drude scattering time τ? Based on this finding, can you explain that rapid decrease in real conductivity with increasing frequency at this point?

   c) Plot the reflectivity R as a function of energy for normal incidence. Explain the relationship of reflectivity with skin depth.

2. You are familiar with the properties of an ellipse, where light emitted at one of the two foci, and reflected at the internal surface will be refocused at the other focus. Now we consider an ellipse made of some dielectric n_2 and the transmission of light through its interface into the surrounding space described by n_1. If a point light source is placed at the focus F' of that ellipse, show that a plane wave will emerge on the right side propagating parallel to the long axis.

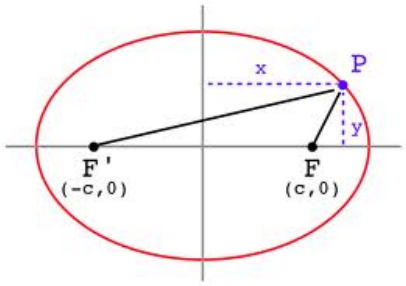

Figure 1:

3. A biconvex thin lens ($n = 1.4$) shall have 10 cm focal length.

   a) What radius of curvature does it have (both surfaces have identical curvature)?

   b) An object is placed at a distance of 2 cm in front of the lens. Calculate the distance of the image. Also sketch a corresponding ray diagram.