Spring 2017 Written Comprehensive Exam
Opti 501, Day 1

System of units: MKSA

Inside a homogeneous, isotropic, non-magnetic, dielectric medium of refractive index $n(\omega)$, a monochromatic, homogeneous plane-wave propagates along the z-axis. The plane-wave is linearly-polarized along the x-axis, and the medium is transparent, that is, $n(\omega)$ is real and positive.

4 Pts a) Write expressions for the plane-wave's electric and magnetic fields, $\boldsymbol{E}(\boldsymbol{r},t)$ and $\boldsymbol{H}(\boldsymbol{r},t)$, in terms of the E-field amplitude E_0, the angular frequency ω, the refractive index $n(\omega)$, the speed of light in vacuum c, and the impedance of free space Z_0.

2 Pts b) Express the dielectric function $\varepsilon(\omega)$ and the electric susceptibility $\chi(\omega)$ as functions of the refractive index $n(\omega)$.

4 Pts c) Write an expression for the polarization distribution $\boldsymbol{P}(\boldsymbol{r},t)$ in terms of E_0, ω, c, ε_0 and $n(\omega)$. What are the distributions of the electric bound-charge and bound-current densities, $\rho_{\text{bound}}(\boldsymbol{r},t)$ and $\boldsymbol{J}_{\text{bound}}(\boldsymbol{r},t)$, in the medium?

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Opti 501, Day 2

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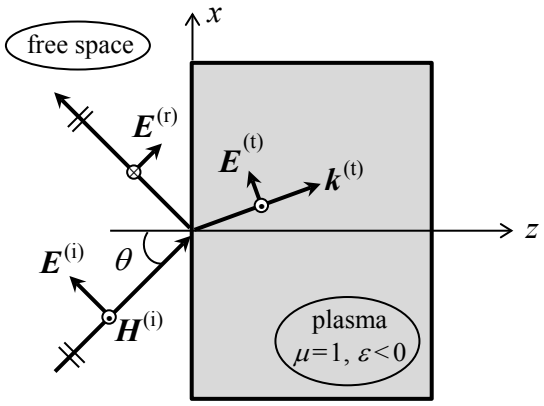
A *p*-polarized monochromatic plane-wave arrives from free-space at the flat surface of a plasma at an oblique angle θ, as shown. The optical properties of the plasma are specified by its permittivity $\varepsilon(\omega)$, a real-valued *negative* entity, and by its permeability $\mu(\omega) = 1$.



2 Pts a) Write expressions for the *E* and *H* fields of the incident beam as functions of space and time.

2 Pts b) Write expressions for the *E* and *H* fields of the reflected beam as functions of space and time.

2 Pts c) Write expressions for the *E* and *H* fields of the beam transmitted into the plasma as functions of space and time. Identify the real and imaginary components of the *k*-vector, and relate them to the various parameters of the system.

2 Pts d) Match the boundary conditions at the plasma surface, and obtain expressions for the Fresnel reflection and transmission coefficients ρ_p and τ_p, respectively.

2 Pts e) Show that the reflectivity of the plasma is always 100%, irrespective of the incidence angle θ, or of the exact value of $\varepsilon(\omega)$. Explain the apparent contradiction between a 100% reflectance at the surface and the existence of electromagnetic field energy inside the plasma.