PHYS 942 MIDTERM Exam

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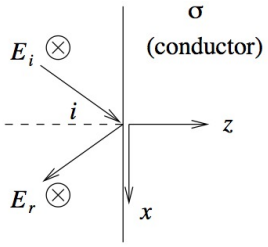
PHYS 942
October 25, 2018, 12:30 - 2:00 pm
251 DeMeritt

Name, please write clearly: _____

Note: Open book (Zingwall, Jackson). 250 points max, 100 are a perfect score! Please write clearly. **Show all your steps!**

1. (*50 points*) EM wave penetration: A plane polarized electromagnetic wave of frequency ω is incident with angle I on a flat surface of an excellent conductor ($\mu = \mu_0$, $\epsilon = \epsilon_0$, and $\sigma \gg \omega\epsilon_0$), which fills the region $z>0$. Consider only linear polarization perpendicular to the plane of incidence as indicated in the figure.



If the incident wave is given by $\mathbf{E} = \mathbf{E}_i e^{i(\mathbf{k}\cdot\mathbf{x}-\omega t)}$, show that the magnitude of the electric field inside the conductor is

$$E_c = E_i \gamma \cos I e^{-z/\delta} e^{i(kx \sin I + z/\delta - \omega t)}$$

with $\delta = \sqrt{2/\omega\mu_0\sigma}$ and $\gamma = (1-i)\sqrt{2\epsilon_0\omega/\sigma}$ (note that I capitalized the angle of incidence I to avoid confusion with the complex constant i).

2. (*50 points*) EM waves in conductors:
   (a) Starting from Maxwell's equations and Ohm's law derive the wave equation in a conductor with conductance σ.
   (b) Show that the solution for a plane wave looks the same as for a non-conducting medium, except that the wave vector is complex, i.e., $\tilde{k} = k + i\alpha$.
   (c) What is the physical significance of $d = 1/\alpha$?

3. (*50 points*) Consider a plane, linearly polarized wave incident on a reflecting surface with normal vector $\mathbf{n}$, such that total internal reflection occurs, i.e., $n_1 > n_2 = 1$. The polarization vector (i.e., $\mathbf{E}$) of the incident wave makes an angle of 45° to the surface spanned by the wave vectors of the incident and reflected waves. Calculate the polarization state of the reflected wave in terms of n_1, the incidence angle, and the unit vectors $\mathbf{e}_1 = \mathbf{k}\times\mathbf{n}/|k||n|$ and $\mathbf{e}_2 = \mathbf{n}\times\mathbf{e}_1/|n|$, i.e., E_1 and E_2 in $\mathbf{E} = (E_1\mathbf{e}_1 + E_2\mathbf{e}_2)e^{i(\mathbf{k}_2\cdot\mathbf{x}-\omega t)}$ where $\mathbf{k}_1$ and $\mathbf{k}_2$ are the wave vectors of the incident and the reflected wave, respectively.

4. (*50 points*) Conceptual questions. Answer each in 1-3 sentences.

   (a) Why are waveguides used instead of wires to transmit microwaves?

   (b) What is the physical meaning of the Q value of a resonant cavity?

   (c) What is the physical meaning of the skin depth?

   (d) How can you decrease the reflectivity of a glass surface at a specific frequency?

   (e) Which longitudinal field component does not occur in a TE mode wave?

   (f) Name at least two methods to produce linearly polarized light.

   (g) Could aliens orbiting the Earth in a spaceship listen to an AM radio station?

   (h) Could the aliens watch TV (which operates at 50-500 MHz)?

   (i) Why are metals shiny?

   (j) Are there any frequencies at which metals are transperent for EM waves?

   (k) What is the typical frequency and wavelength of FM radio?

   (l) What is the typical frequency and wavelength of cell phone signals?

   (m) What is anomalous dispersion?

   (n) How are waves in a waveguide different from waves in free space?

   (o) What causes the losses in waveguides?

   (p) Can waves in a waveguide propagate at any frequency?

   (q) Name at least 3 wave modes that are dispersive.

   (r) Name at least 3 wave bands at which the atmosphere is opaque.

   (s) What is bi-refringence?

   (t) Name one bi-refringent medium.

5. (*50 points*) Rectangular cavity:

   (a) Consider the TE mode in a rectangular cavity of dimensions $a\times b\times c$. Calculate the eigenfrequencies assuming perfectly conducting walls.

   (b) Calculate the fields for the eigenmode with the lowest frequency, assuming $a < b < c$.