Fundamentals of Electromagnetic Fields and Waves: I

Fall 2005, EE 30348, Electrical Engineering, University of Notre Dame

Mid Term Exam: II

Please show your steps clearly and sketch figures wherever necessary. Points will be awarded for correct steps shown in the solutions.

Fundamental constants:

$\epsilon_0 \approx \frac{1}{36\pi} \times 10^{-9}$ F/m.

$\mu_0 = 4\pi \times 10^{-7}$ H/m.

$\eta_0 = \sqrt{\mu_0/\epsilon_0} \approx 120\pi\ \Omega$.

Problem 1 (8 Points)

An infinitely long conducting wire of radius a carries a current I. As an engineer, you are required to design the space around the wire such that the magnetic field B at a distance $2r_0$ from the wire is *twice* in magnitude of that at a distance r_0 from the wire. How can you achieve that? Give examples of any materials you think might be useful.

Problem 2 (4 Points)

Explain what is meant by the *skin depth* of a material medium. Given that the electric field of an electromagnetic wave in a material medium is given by $\hat{E}(z,t) = E_m^+ e^{-\alpha z} e^{j(\omega t - \beta z)}$, where $\alpha = \omega\sqrt{\mu\epsilon/2}[\sqrt{1+(\frac{\sigma}{\omega\epsilon})^2}-1]^{1/2}$, explain what the skin depth is for a metal, which might be approximated as an infinitely conductive material ($\sigma \to \infty$).

Problem 3 (8 Points)

The earth's surface receives close to 1000 W/m^2 solar energy on a normal sunny day. Assuming (crudely) that the earth's atmosphere is characterized by the material parameters of free space, (i.e., $\epsilon = \epsilon_0$ and $\mu = \mu_0$), and that the power is averaged over a period of the electromagnetic waves (EM) from the sun,

a) find the magnitude of the electric field in the EM wave, and
b) find the magnitudes of the magnetic field intensity (H) and the magnetic field (B). Make sure you use to correct units in your calculation.