Homework #3 (10 points) - Show all work on the following problems:

Problem 1 (2 points): Imagine a parallel plate capacitor immersed in sea water with permittivity $\varepsilon = 81\varepsilon_0$, permeability $\mu=\mu_0$, and resistivity $\rho = 0.23\ \Omega\ m$. If the capacitor has a sinusoidally varying voltage $V(t) = V_0 \cos(2\pi\nu t)$ with amplitude V_0 and frequency $\nu = 4 \times 10^8$ Hz, what is the ratio between the amplitudes of the conduction current and the displacement current $\vec{J_d} = \frac{\partial \vec{D}}{\partial t}$?

Problem 2 (3 points): By using the Poynting vector, calculate the total electromagnetic energy per unit time transported down a coaxial cable consisting of an inner cylinder with radius a and an outer cylinder with radius b, as in Example 7.13 in the book. Assume the two conductors are held at a potential difference V, with current I flowing along the surface of the inner cylinder and back along the surface of the outer cylinder.

Problem 3 (3 points): Find the electromagnetic force between two equal point charges q separated by a distance $2a$, by integrating Maxwell's stress tensor over the plane equidistant between the two charges.

Problem 4 (2 points): A charged parallel-plate capacitor (two plates with area A, separated by distance d, carrying charge $+Q$ and $-Q$) has its positively charged plate in the x-y plane ($z=0$), and its negatively charged plate at $z = d$. There is thus a uniform electric field E pointing in the +z direction between the plates. Now imagine that there is also a uniform magnetic field B pointing in the +x direction.

4a (1 point): Find the magnitude and direction of the electromagnetic momentum in the space between the plates, in terms of E, B, A, and d.

4b (1 point): Now assume that a wire with resistance R is connected between the plates, along the z-axis, so that the capacitor slowly discharges. The current through the wire will experience a magnetic Lorentz force. What is the magnitude and direction of the total impulse (Impulse = $\int \vec{F}\,dt$) delivered to the system by that force during the discharge, in terms of E, B, A, and d?