1. Dielectrics that are somewhat conducting are said to be lossy. For example, most natural substances, such as wood or wheat, show a slight conductivity that is associated with the presence of water. Now, an alternating current is applying to a parallel-plate capacitor containing a lossy dielectric as shown in Fig. 1. It is convenient to express the conductivity in terms of a complex permittivity. What are the real and the imaginary part of the complex permittivity? (10%)

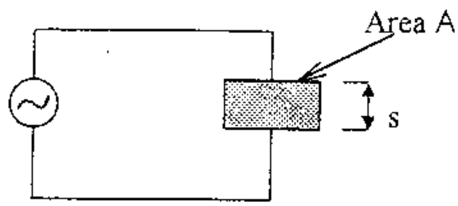

Fig. 1

2. Figure 2 shows the hysteresis loop for a nickel-iron alloy called Deltamax. What is the approximate value of the power dissipation per cubic meter and per cycle when the material is driven to saturation both ways? (10%)

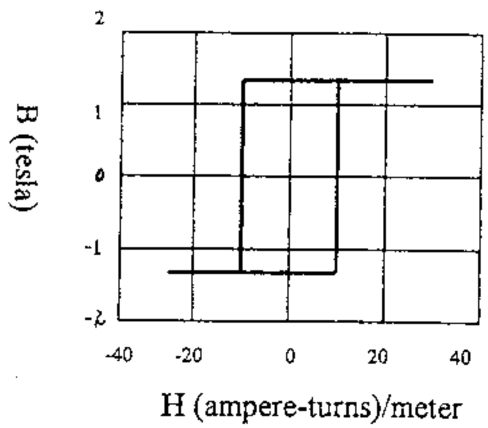

Fig. 2

3. Assume the inner conductor of a coaxial cable to have a radius of a meter and the outer conductor to have an inner radius of b meter and an outer radius of c meter. Assume also the cable's axis is along the z-axis and the cable is infinite long. Show that $\nabla \times \vec{H} = \vec{J}$ for the field in each conductor of a coaxial cable. The field in the inside conductor (r < a) is $H_\phi = \dfrac{Ir}{2\pi a^2}$ and in the outside conductor (b < r < c) is

$$H_\varphi = \frac{I(c^2 - r^2)}{2\pi r(c^2 - b^2)}$$ (15%)

4. The dielectric of a parallel-plate capacitor has a permittivity that varies as $\varepsilon_{ro} + ax$, where x is the distance from one plate. The area of a plate is A, and their spacing is s. (a) Find the capacitance. (b) Show that, if ε_r varies from ε_{ro} to $2\varepsilon_{ro}$, then capacitance C is 1.44 times as large as if a were zero. (c) Find polarization P from the values of displacement field D and electric field E for that case. (d) Deduce the value of volume bound charge density ρ_b. (e) Show that $\rho_b = -(\varepsilon_o / \varepsilon_r)\vec{E} \bullet \nabla \varepsilon_r$ in a nonhomogeneous dielectric, if volume free charge density $\rho_f = 0$. (f) Use the result of (e) to calculate ρ_b. The result should be the same as that of (d). (25%)
5. Suppose the effect of a magnetic field is to induce a magnetic dipole moment of 10^{-23} A-m^2 per atom. Let there be 10^{27} atoms/m^3. Find the surface current density at surface making an angle of 45° with $\vec{M}$. (10%)
6. Show that the total force on a closed circuit carrying a current I in a uniform magnetic field is zero. Is there a torque? If there is, what is the torque? (10%)
7. Consider a perfect dielectric medium z < 0 bounded by a perfect conductor z > 0, as shown in Fig. 3. Let the fields in the dielectric medium be given by the superposition of (+) and (-) uniform plane waves propagating normal to the conductor surface, that is,

$$\vec{E} = E_1 \cos(\omega t - \beta z)\hat{i} + E_2 \cos(\omega t + \beta z)\hat{i}$$

$$\vec{H} = \frac{E_1}{\eta}\cos(\omega t - \beta z)\hat{j} - \frac{E_2}{\eta}\cos(\omega t + \beta z)\hat{j}$$

where $\beta = \omega\sqrt{\mu\varepsilon}$ and $\eta = \sqrt{\frac{\mu}{\varepsilon}}$. Investigate the relationship between E_2 and E_1.

Also, find the total electric and magnetic fields in the dielectric and the current density at the surface between the dielectric and the conductor. (20%)

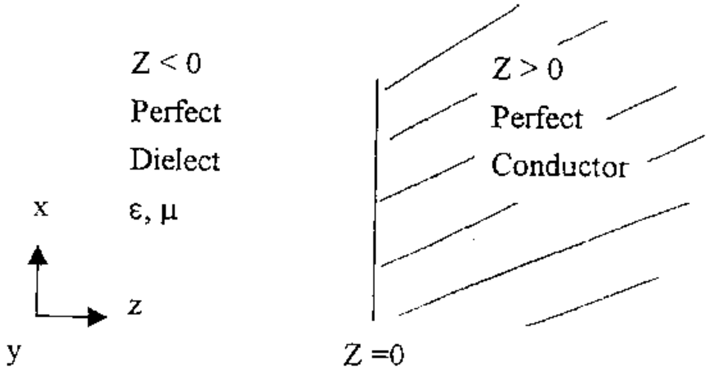

Fig. 3 A perfect dielectric medium bounded by a perfect conductor