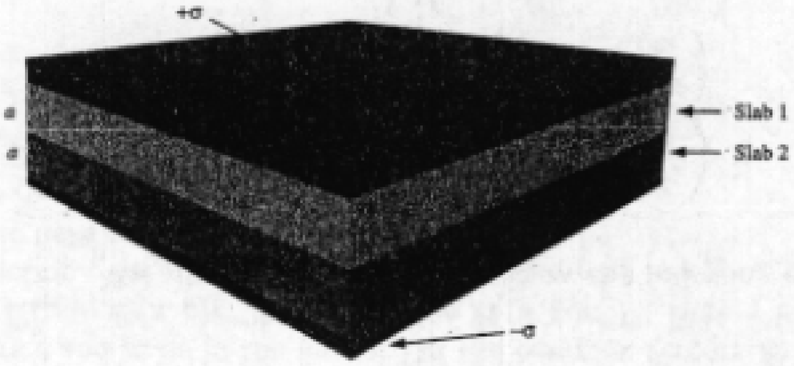
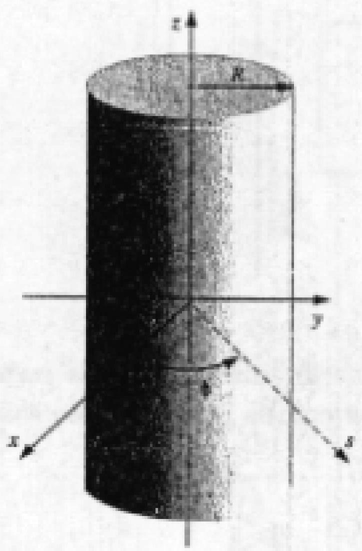
1.(15%) A point charge q is situated a distance a from the center of a *neutral* conducting sphere of radius R. Find the force of attraction between the point charge and sphere.

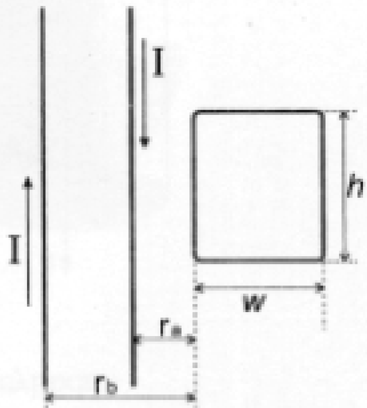
2.(20%) The space between the plates of a parallel-plate capacitor is filled with two slabs of linear dielectric material. Each slab has thickness a, so the total distance between the plates is $2a$. Slab 1 has a dielectric constant of 2, and slab 2 has a dielectric constant of 1.5. The free charge density on the top plate is σ and on the bottom plate is $-\sigma$. (a) Find the electric displacement D, elecrric field E, and polarization P in each slab. (b) Find the potential difference between the plates. (c) Find the location and amount of all bound charge.



3.(15%) A long circular cylinder of radius R carries a magnetization $M = ks^2\hat{\phi}$, where k is a constant, s is the distance from the axix, and $\hat{\phi}$ is the usual azimuthal unit vector. Find the magnetic field B due to M, for points inside and outside the cylinder.



4 (10%) A pair of parallel wires carries equal currents I in opposite directions, and I increases at the rate $\frac{dI}{dt}$. Calculate the induced electromotance in the closed rectangular wire loop.

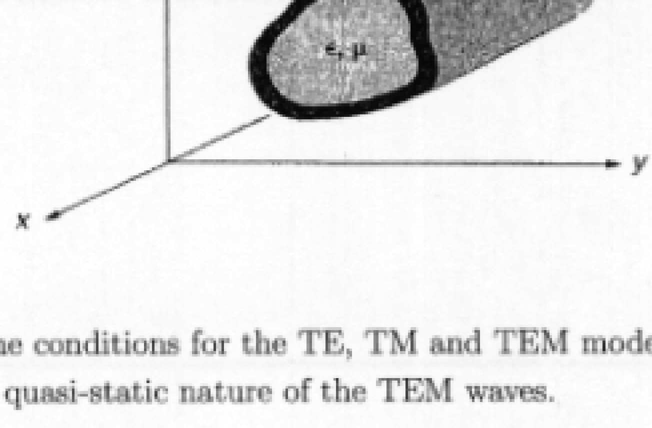


5 (20%) State and prove the Poynting's theorem.

6 (a) (10%) Consider a hollow, perfectly conducting waveguide pipe, filled with a perfect dielectric of parameters ϵ and μ, as in the figure. Let the complex vectors $\boldsymbol{E}$ and $\boldsymbol{H}$ in the waveguide be of the form $\boldsymbol{E}_{\text{tot}} = \boldsymbol{E}(x,y)e^{-\gamma z}$, and $\boldsymbol{H}_{\text{tot}} = \boldsymbol{H}(x,y)e^{-\gamma z}$. Here γ is the propagation coefficient in the z direction. We allow γ to be complex. Show the following expressions for the electric and magnetic field components:

$$E_x = -\frac{1}{K^2}\left(\gamma\frac{\partial E_z}{\partial x} + j\omega\mu\frac{\partial H_z}{\partial y}\right) ,$$
$$E_y = -\frac{1}{K^2}\left(\gamma\frac{\partial E_z}{\partial y} - j\omega\mu\frac{\partial H_z}{\partial x}\right) ,$$
$$H_x = -\frac{1}{K^2}\left(-j\omega\epsilon\frac{\partial E_z}{\partial y} + \gamma\frac{\partial H_z}{\partial x}\right) ,$$
$$H_y = -\frac{1}{K^2}\left(-j\omega\epsilon\frac{\partial E_z}{\partial x} + \gamma\frac{\partial H_z}{\partial y}\right) ,$$

where $K^2 = \gamma^2 + \beta^2$, $\beta^2 = \omega^2\epsilon\mu$, and ω is the angular frequency of time-harmonic fields $\boldsymbol{E}$ and $\boldsymbol{H}$.



(b) (5%) What are the conditions for the TE, TM and TEM modes?

(c) (5%) Discuss the quasi-static nature of the TEM waves.