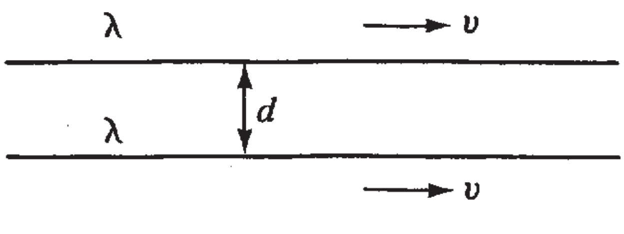
1. A point charge q is imbedded at the center of a sphere of linear dielectric material with susceptibility χ_e and radius R.
   (a) Find the electric field $\mathbf{E}(\mathbf{r})$ and the Polarization $\mathbf{P}(\mathbf{r})$ for $r < R$. (8%)
   (b) Find the volume bound charge density $\rho_b(r)$ for $r < R$. (6%)
   (c) What is surface bound charge density $\sigma_b(r)$ for $r = R$? (3%)
   (d) What is the total bound charge at the surface ($r = R$)? (4%)
   (e) What is the total bound charge at the center of the sphere ($r = 0$)? (4%)

2. Consider two infinite straight line with line charge density λ, a distance d apart, moving along at a constant speed υ, see figure in below.
   (a) Apply Gauss's law to find the electric field on one of the wire. (4%)
   (b) What is the electrical force per unit length between two wires? (2%)
   (c) Apply Ampere's law to find the magnetic field at each wire and at the position r located between two wires ($r < d$ and r is the distance from the top wire). (8%)
   (d) Find the magnetic force per unit length between two wires (4%)
   (e) How fast would υ have to be in order for the magnetic attraction to balance the electrical repulsion? (4%)
   (f) Work out the actual number of υ. Is this a reasonable sort of speed? (3%)



3. A plane wave originating in medium 1 ($\epsilon_1, \mu_1 = \mu_0, \sigma_1 = 0$) is incident normally on a plane interface with medium 2 ($\epsilon_2 \neq \epsilon_1, \mu_2 = \mu_0, \sigma_2 = 0$). Under what condition will the electric field at the interface be a maximum? A minimum? Where ϵ, μ, and σ is permittivity, permeability, and conductivity of medium, respectively. (10%)

4. The angle $\theta_{B\parallel}$ is known as the **Brewster angle** of no reflection for the case of parallel polarization. A solution for this equation always exists for two contiguous nonmagnetic media. Thus if $\mu_1 = \mu_2$, a reflection-free condition is obtained when the angle of incidence in medium 1 equals the Brewster angle $\theta_{B\parallel}$.

(1) Prove that $\sin\theta_{B\parallel} = \frac{1}{\sqrt{1+(\epsilon_1/\epsilon_2)}}$ (10%)

(2) If the dielectric constant of glass is 8. Determine the Brewster angle for parallel polarization and the corresponding angle of transmission. (10%)

5. Without deriving any new equations, roughly sketch the electric and magnetic field lines in a typical transverse plane of a circular waveguide.

(1) For TM_{11} mode (5%)

(2) For TE_{01} mode (5%)

(3) Determine the cutoff frequencies for TM_{11} and TE_{10} modes in an air-filled circular waveguide of radius a. (10%)