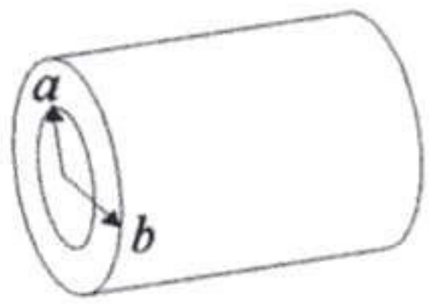
1. (20%) There is a uniformly charged solid sphere of radius R and total charge q.
(a) Find the electric field outside the sphere.
(b) If the sphere is a conductor, find the electric field inside the sphere.
(c) If the sphere is nonconductive, find the electric field inside the sphere.

2. (15%)

(a) Prove that the electric potential energy of an ideal dipole $\vec{p}$ in an electric field $\vec{E}$ is given by $U = -\vec{p} \cdot \vec{E}$.

(b) Show that the electric field $\vec{E}$ causes a torque $\vec{\tau} = \vec{p} \times \vec{E}$ on the dipole.

3. (15%) Find the capacitance per unit length of two coaxial metal cylindrical tubes, of radii a and b.



4. (10%) Start with the general expression for a vector potential :
$\vec{A}=\int_V \frac{\mu \vec{J} dV'}{4\pi R}$, and find the magnetic field strength about an infinite long wire carrying a current I.

5. (15%)

a. Write down the Maxwell equations in the presence of a charge density ρ and a current density $\vec{J}$.

b. Use the Faraday's law to show the following statement:
The tangential component of an electric field is continuous at the surface.

6. (25%)

a. In a conductor $\vec{J}=\sigma\vec{E}$ and $\rho=0$. Derive the wave equation for $\vec{E}$ and $\vec{H}$ in a conductor.

b. If $\vec{E}=\hat{x}E_x(z,t)$, show that $E_x(z,t)$ must satisfy the wave equation:

$$\frac{\partial^2 E_x}{\partial z^2}-\mu\sigma\frac{\partial E_x}{\partial t}-\mu\varepsilon\frac{\partial^2 E_x}{\partial t^2}=0.$$

c. Show that $E_x(z,t)=E_0\exp(-\alpha z)\cos(\omega t-\beta z)$ is a solution and find α and β in terms of $\omega,\mu,\varepsilon,$and σ.