Problem 1)
Two concentric conducting spheres of inner and outer radii a and b, respectively, carry charges $\pm Q$. The empty space between the spheres is half-filled by a hemispherical shell of dielectric (of dielectric constant ϵ/ϵ_0), as shown in the figure.
(a) Find the electric field everywhere between the spheres.
(b) Calculate the surface-charge distribution on the inner sphere.
(c) Calculate the polarization-charge density induced on the surface of the dielectric at $r = a$.

Problem 2)
A right-circular solendoid of finite length L and radius a has N turns per unit length and carries a current I. Show that the magnetic induction on the cylinder axis on the cylinder axis in the limit $NL \to \infty$ is

$$B_z = \frac{\mu_0 NI}{2}(\cos\theta_1 + \cos\theta_2), \tag{1}$$

where $\theta_{1,2}$ are defined in the figure.

Let us define the left end of the cylinder to be at position $z = 0$ and the right to be at $z = L$. At position z, the angles θ_1 and θ_2 are defined as

$$\cos\theta_1 = \frac{z}{\sqrt{z^2 + a^2}}, \quad \cos\theta_2 = \frac{L - z}{\sqrt{(L - z)^2 + a^2}}. \tag{2}$$

Ampère's law in integral form (for magetostatics) is

$$\int \vec{\boldsymbol{B}} \cdot \mathrm{d}\vec{\boldsymbol{l}} = \mu_0 I_{\text{enc}}. \tag{3}$$

If we place a rectangular loop that straddles only the upper portion of the solenoid, then we have

$$d. \tag{4}$$

Problem 3)
A cylindrical conductor of radius a has a hole of radius b bored parallel to, and centered a distance d from, the cylinder axis ($d + b < a$). The current density is uniform throughout the remaining metal of the cylinder and is parallel to the axis. Use Ampère's law and principle of linear superposition to find the magnitude and the direction of the

magnetic-flux density in the hole.