1. (25 pts) A long coaxial cable consists of a conducting inner cylinder of radius $a$ and a thick outer conducting cylinder of inner radius $b$ and outer radius $c$ (Note: $a < b < c$). The surface charge density on the inner cylinder is $\sigma_a$.

a) Find the surface charge densities $\sigma_b$, $\sigma_c$.

b) Find the electric field in each of the four regions:
   (i) inside the inner cylinder, $s < a$.
   (ii) between the cylinders, $a < s < b$.
   (iii) inside the thick outer cylinder, $b < s < c$.
   (iv) outside the cable, $s > c$.

b) If the outer cylinder is now grounded, find the capacitance per unit length of the arrangement.

2. (25 pts) A surface charge density $\sigma(\phi) = \sigma_0 \cos(3\phi)$ is glued over the surface of an infinite cylinder of radius $R$ ($\sigma_0$ is a constant).

Find the electric potential $V(s, \phi)$ inside and outside the cylinder.

3. (25 pts) A steady current $I$ flows down a long hollow cylindrical wire (inner radius $a$, outer radius $b$). The volume current density $\vec{J} = \frac{C}{s^2} \hat{z}$, where $C$ is a constant and $\hat{z}$ is in the direction of the current $I$.

a) Determine the constant $C$.

b) Determine the magnetic field for all $s$, i.e., $s < a$; $a < s < b$; $s > b$.

4. (25 pts) A parallel plate capacitor is filled half and half with two dielectrics with dielectric constants $\varepsilon_{r1} = 3$ and $\varepsilon_{r2} = 2$ as shown.

a) Determine the capacitance of the arrangement in terms of the original capacitance $C_0$ with no dielectric material present ($C_0 = \varepsilon_0 A/d$). The area of a plate is $A$ and $d$ is the distance between the plates.

b) For a given potential difference $V$ between the plates, find the free and bound surface charge densities on all surfaces.
5. (25 pts) a) Find the force of repulsion between two magnetic dipoles $\vec{m}_1$ and $\vec{m}_2$ oriented as shown a distance $r$ apart.

b) Assume the two dipoles have the same dipole moment $m$ and mass $M = 30$ gms. They are donut shaped so they can slide frictionlessly on a vertical rod. If the upper one “floats” at a distance of 1.5 cm above the lower one, determine the dipole moment $m$ of the magnets.

The magnetic field of a pure dipole is given by:

$$\vec{B} = \frac{k_m}{r^3} \left[ 3(\vec{m} \cdot \hat{r})\hat{r} - \vec{m} \right]$$

6. (25 pts) A current flows down a long straight wire of radius $R$. The volume current density is given by: $\vec{J} = \chi_m \vec{z}$. The wire is made of linear material (copper, say, or aluminum) with magnetic susceptibility $\chi_m$.

a) Determine the magnetic field a distance $s$ from the axis.

b) Determine the bound currents.

c) Calculate the net bound current flowing down the wire.