Choose 3 out of the following 5 questions, clearly indicating which you have chosen. All problems have equal weight.

1. Consider two coaxial metal cylindrical tubes, of radii $a$ and $b$ (Fig. below). The inner shell has charge $-\lambda$ per unit length, while the outer shell has charge $\lambda$ per unit length.

![Diagram of coaxial cylinders](image)

a) Find the capacitance per unit length of the system  
b) Find an expression for the energy per unit length stored in the capacitor.

2. A large slab of dielectric material with a plane surface is inserted into an electric field that is at an angle $\theta$ with the normal to the surface of the dielectric (see figure below). The dielectric constant of the material is $k = \varepsilon/\varepsilon_0$. Find:
   a) The relationship between $k$ and the angles $\theta$, $\theta_i$.
   b) The magnitude of the electric field and the magnitude of the displacement vector inside the dielectric in terms of their magnitudes outside and the angles $\theta$, $\theta_i$.

![Diagram of dielectric slab](image)
3. (a) Imagine this. You are in a room through which a power line (pair of wires) runs in through one wall and out through the opposite wall. There is a DC generator behind one wall and a motor behind the other, but you are not told which is which. The wires run side by side with some separation between. From measurements entirely within the room, how can you determine which is the generator and which is the motor? Explain your answer, preferably using a diagram representing your observations.

(b) Down the hall is another room with just one wire running through it carrying a DC current of magnitude \( I \) uniformly distributed over its area. The wire has radius \( a \) and conductivity \( \sigma \). What is the radial power flow into this section of wire of length \( L \)? How is it related to resistive heating in the wire?

4. An iron rod of length \( L \) and square cross section (side = \( a \)) is given a uniform longitudinal magnetization \( M \), and then bent around into a circle with a narrow gap (width = \( w \)). Find the following:
   (a) Magnetic field intensity \( H \) at the center of the gap.
   (b) \( H \) within the iron ring.
   (c) Magnetic induction \( B \) at the center of the gap.
   (d) \( B \) within the iron ring.

5. Calculate the magnetic pressure acting on a 10 Tesla superconducting magnet solenoid. You may consider the solenoid as very long to neglect end effects. Will it tend to collapse or expand?

\[ \mu_0 = 4\pi \times 10^{-7} \text{ Tm/A} \]