Closed Book

1a. A very long conducting cylindrical rod of length L with a total charge +q is surrounded by a conducting shell (also of length L) with a total charge -2q. Use Gauss' law to find the electric field at points outside the conducting shell, and in the region between the shell and the rod.

1b. Two large parallel nonconducting sheets have identical distributions of positive charge with surface charge density +\( \sigma \). What is E at points above the sheets, between them and below them?

1c. A sphere of radius a and charge +q uniformly distributed throughout its volume is concentric with a spherical conducting shell of inner radius b and outer radius c. This shell has a net charge -q. Find expression for the electric field as a function of the radius r. r<a, a<r<b, and r>c.
2a. We derived an expression for the potential of a dipole:

\[ V = \frac{Qd \cos \theta}{4\pi \varepsilon_0 r^2} \]

Determine the spherical components of the electric field \( E_r \), \( E_\theta \), \( E_\phi \).

2b. We have a system with two concentric spherical shells with total charge on the center one \( +q \) and outer one \( -q \). Write an expression for the electric field in the region between the shells. Now find an expression for the potential in this region.

2c. A charge \( +Q \) is located at \((0, 0, h)\) above a conductor at zero potential. A second charge \( +2Q \) is located at \((0, 0, 2h)\). Write an expression for the potential at \((0, 0, 4h)\) due to the two charges and the ground plane. Now write an expression for the electric field at this point.

3a. Using the following diagrams, the conservative property of the electric field and Gauss' Law find the relationship between \( E_{1n} \) and \( E_{2n} \) in addition to the relation between \( D_{1n} \) and \( D_{2n} \).

3b. Derive the Capacitance of a simple parallel plate capacitor with separation \( d \), \( \varepsilon \), and area \( A \). First write the electric field with charge \( Q \) and find the voltage. \( C = \frac{Q}{V} \). What is the electrostatic energy in the system? Write it in terms of charge and Capacitance. Now if we pull the dielectric out, keeping the charge constant, how does the energy change? How do we explain this?

3c. Now solve for the capacitance with two dielectrics as shown in the figure.