1. (Purcell 10.3) What is the magnitude of the dipole moment of each of the charge distribution in parts (a), (b), and (c) of the figure? What is the direction of the dipole moment vector $\mathbf{p}$?

2. (Purcell 10.9) What is the direction of the force on the central dipole caused by the field of the other two dipoles? Calculate the magnitude of the force.

3. (Purcell 10.11) A field line in the dipole field is described in polar coordinates by the very simple equation $r = r_0 \sin^2 \theta$, in which $r_0$ is the radius at which the field line passes through the equatorial plane of the dipole. Show that this is true by demonstrating that at any point on that curve the tangent has the same direction as the dipole field.

4. (Purcell 10.14) The figure shows three capacitors of the same area and plate separation. Let $C_0$ be the capacitance of the vacuum capacitor shown on top. Each of the others is half-filled with a dielectric, with the same dielectric constant $\epsilon$ but in a different geometry, as shown. Find the capacitance of each of these 2 capacitors (neglect edge effects).
5. (Purcell 10.15) The electric dipole moment of the water molecule is $1.84 \times 10^{-18}$ esu-cm. Imagine that all the molecular dipoles in a cup of water could be made to point down. Calculate the magnitude of the resulting surface charge density at the upper water surface, and express it in electrons per cm$^2$.

6. (Purcell 10.16) In Lecture 21 and in Section 10.10 of the textbook, the fact that the electric field is uniform inside the polarized sphere was deduced from the form of the potential on the boundary. You can also prove it by superposing the internal electric fields of two balls of charge whose centers are separated.

   (a) Show that inside a spherical, uniform charge distribution $\mathbf{E}$ is proportional to $r$.

   (b) Now take two spherical distributions with density $\rho$ and $-\rho$, centers at $C_1$ and $C_2$, and show that the resultant field is constant and parallel to the line from $C_1$ to $C_2$.

   (c) Analyze in the same way the field of a long circularly cylindrical rod which is polarized perpendicular to its axis.

7. (Purcell 10.21) Materials to be used as insulators or dielectrics in capacitors are related with respect to dielectric strength, defined as the maximum internal electric field the material can support without danger of electrical breakdown. It is customary to express the dielectric strength in kilovolts per mil. (One mil is 0.001 inch.) For example Mylar (Dupont polyester film) is rated as having a dielectric strength of 14 kV/mil when it is used in a thin sheet as it would be in a typical capacitor. The dielectric constant $\epsilon$ of Mylar is 3.25. Its density is 1.40 g/cm$^3$.

   (a) Calculate the maximum amount of energy that can be stored in a Mylar-filled capacitor, and express it in J/kg of Mylar.

   (b) Assuming the electrodes and case account for 25% of the capacitor's weight, how high could the capacitor be lifted by the energy stored in it?

8. How long did this problem set take you to complete?