NYU Physics 2 — Problem Set 5

Due by Friday 2002 March 1 at 1pm at Irene Port's office in Meyer 424.

Problem 1

Imagine that you have a glass of water in which all of the water molecules are aligned, so that their positive ends all point upwards. Imagine that each molecule can be treated as a simple dipole consisting of two charges q and $-q$ separated by a small vertical distance a. In this case, the water is like two superimposed charge densities, one positive and one negative, displaced vertically by a tiny distance a. If the water in a glass is in this aligned state, what is the magnitude of the electric field E in the water? Your answer should depend on the product $q\,a$, which is the dipole moment of the water molecule, which you can look up in your book. What would be the potential difference V in volts from the top to the bottom of a glass of water in this aligned state? Do you think this ever happens in nature? Clearly state all your assumptions, approximations and estimates.

Problem 2

Consider a parallel-plate capacitor of width X, depth Y and plate separation h, charged to a total charge Q, filled with a slab of dielectric of constant κ, as discussed in lecture. If you pull the dielectric slab out of the capacitor by a distance x, you change the capacitance, as shown in lecture. Compute the capacitance C and total energy U in the capacitor as a function of x. Compute the force F required as a function of x to remove the slab.

Problem 3

Consider a parallel-plate capacitor of the same dimensions and charge as in Problem 2, but now filled with vacuum, not a dielectric. If you pull apart the plates of the capacitor (ie, increase the separation h), you increase the volume of the capacitor. Compute the integral of the energy density in the electric field to get the total energy U in the capacitor as a function of h. What force F is required to pull apart the plates? Is this the answer you would have expected from, say, $F = q\,E$?