Physics 4L Spring 2010 — Problem set 4, final version
Due Thursday 18 February in class

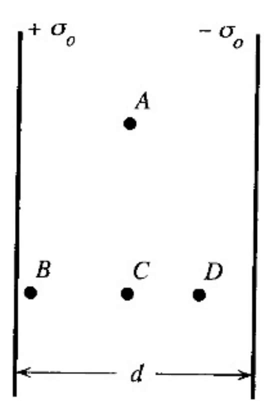
Problems: Wolfson Chapter 22 problems 36, 38, 39, 46, and:

1. A uniformly charged sheet measures 1 m on each side and the total charge on it is 1 μC. Find the field strength (a) 1 cm from the center of the sheet and (b) 1 km from the center of the sheet. In each case explain clearly what approximation you are making and why that approximation is reasonable. Hint: consider how the distance from the sheet compares to the size of the sheet.

2. Consider a dipole and an ion arranged as shown in Chapter 20 problem 63. (*a*) Find an algebraic expression for the force exerted on the ion by the dipole, in terms of the charges Q, q, x, and a. First find an exact expression, and then take the limit $x >> a$ of that expression. (*b*) Find a value for the strength of the force if the ion is a sodium ion with charge 1.6 x 10^{-19} C, the dipole is a water molecule with a dipole moment $p = 2aq$ equal to 6.2 x 10^{-30} C m, and the distance between them is 3 nm.

3. The plasma membrane of a cell has a surface charge density of 2 x 10^{-4} C/m^2 on the outside and an equal magnitude, opposite sign charge density on the inside. The membrane is approximately 5 nm thick. (These numbers are slightly different than the example done in class.)
(*a*) Is the potential difference from the inside of the cell to the outside positive or negative? Explain briefly.
(*b*) How much energy is required for a sodium-potassium pump (the enzyme that transfers Na^+ ions from the inside of the cell to the outside, and K^+ from the outside to the inside) to transport three Na^+ ions from the inside to the outside of the cell? (Assume the energy required is just equal to the electric potential energy gained by the Na^+ ions in moving from the inside to the outside; ignore the energy associated with conformational changes to the enzyme.) The charge of each ion is the elementary charge (1.60 x 10^{-19} C).

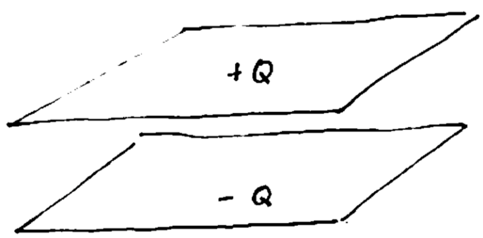
4. Two very large sheets of charge are separated by a distance d. One sheet has surface charge density $+\sigma_0$, and the other surface charge density $-\sigma_0$. A small region near the center of the sheets is shown in the figure to the right.
(*a*) Is ΔV_{AC} positive, negative, or zero? Explain briefly.
(*b*) Is ΔV_{AD} positive, negative, or zero? Explain briefly.
(*c*) Calculate ΔV_{AD} in terms of σ_0, a distance or distances that you define clearly in your solution, and constants (i.e. k or ε_0). To define the distance(s), you can either use a sketch or words.

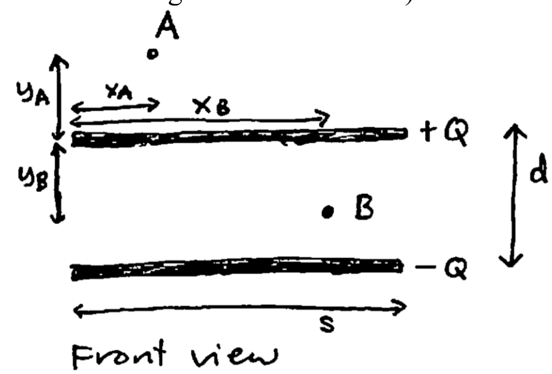


Self-test problem, PS 4 Name ________________________________

You may spend up to 30 minutes on this problem. Do your work on this sheet and turn it in separately. Do not work with others or refer to the textbook, though you may consult the equation sheet posted online. Your score on this problem will not be included in your homework grade; it is solely for feedback to you. (However, you *will* receive credit for one homework problem for completing it.)

Two square conducting plates of side s are given opposite charges $+Q$ and $-Q$ as shown in the diagram. The diagram is not to scale; points A and B are both near the middle of the plates. The points labeled A and B are simply labeling locations in space (there is no charge at these locations).





(*a*) Is the potential difference from point A to point B, ΔV_{AB}, positive, negative, or zero? Explain briefly.

(*b*) Find ΔV_{AB} in terms of Q, distances defined on the diagram (all of which are positive numbers), and fundamental constants. Explain the logic behind your calculation briefly. If you need more space, continue on the back.