MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Department of Physics

8.02 **Fall 2007**

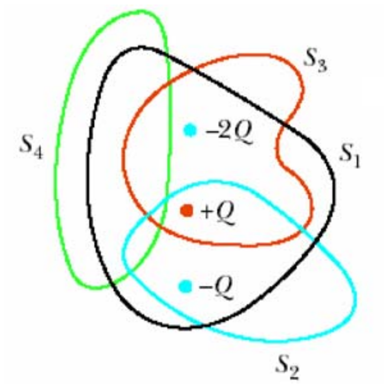
Turn in at your table labeled with your name and group (e.g. L01 6B)

Problem Set 2
Due: Wednesday, September 19 at beginning of class (before 10:15/12:15)

<u>Warm Up</u>

Problem 1: Closed Surfaces

Four closed surfaces, S_1 through S_4, together with the charges –2Q, Q, and –Q are sketched in the figure at right. The colored lines are the intersections of the surfaces with the page. Find the electric flux through each surface.



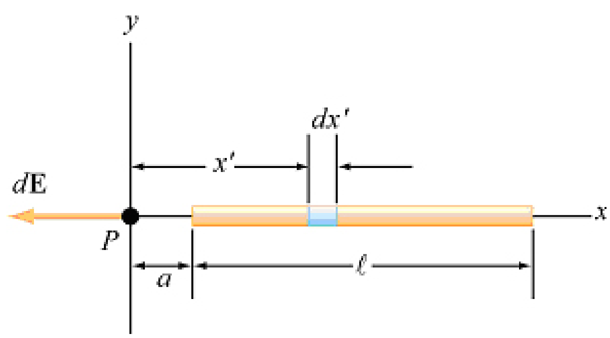
Problem 2: Field on Axis of a Line Charge

A wire of length l has a uniform positive linear charge density and a total charge Q. Calculate the electric field at a point P located along the axis of the wire and a distance a from one end:

a. Give an integral expression for the electric field at point P in terms of the variables used in the figure below.

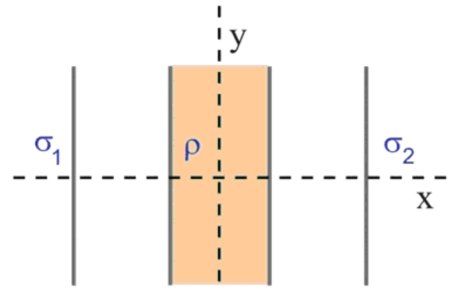
b. Evaluate this integral.

c. In the limit that the length of the rod goes to zero, does your answer reduce to the right expression?



Exam Problem

Problem 3: Charged Slab & Sheets



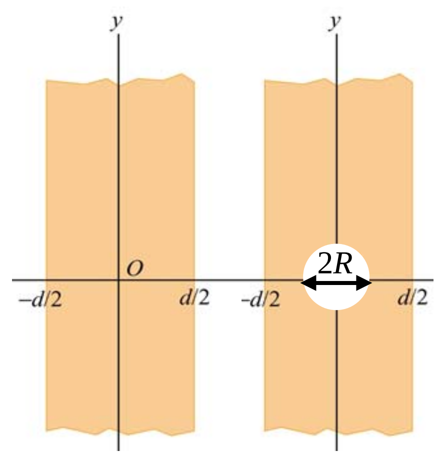
An infinite slab of charge carrying a charge per unit volume ρ has its boundaries located at x = –2 meters and x = +2 meters. It is infinite in the y direction and in the z direction (out of the page). Two similarly infinite charge sheets (zero thickness) are located at x = –6 meters and x = +6 meters, with area charge densities σ_1 and σ_2 respectively. In the accessible regions you've measured the electric field to be:

$$\vec{\mathbf{E}} = \begin{cases} 0\,\hat{\mathbf{i}} & x < -6\text{ m} \\ -10\,\text{V/m}\,\hat{\mathbf{i}} & \text{-6 m} < \text{x} < \text{-2 m} \\ 10\,\text{V/m}\,\hat{\mathbf{i}} & \text{6 m} > \text{x} > \text{2 m} \\ 0\,\hat{\mathbf{i}} & x > +6\text{ m} \end{cases}$$

(a) Use Gauss's Law to find the charge density ρ of the slab. You must indicate the Gaussian surface you use on a figure. You can use the symbol ε_o in your answer.
(b) Use Gauss's Law to find the two surface charge densities of the left and right charged sheets. You must indicate the Gaussian surface you use on a figure. You can use the symbol ε_o in your answer.

Analytic Problems…

Problem 4: Charge Slab



Consider a slab of insulating material which is infinitely large in two of its three dimensions, and has a thickness d in the third dimension. An edge view of the slab is shown in the figure. The slab has a uniform positive charge density ρ.

(a) Calculate the electric field everywhere, both inside and outside the slab.

(b) Now some material is removed around the origin, leaving a hole of radius R ($R < d/2$) there. What is the electric field on the x-axis for $|x| < d/2$?

(c) A small charge q with mass m is now placed on the x-axis at the right hand edge of the hole. How large and what sign must the charge q be so that it will undergo simple harmonic motion and have a velocity $v_{\max}$ at the origin?

Problem 5: Uniformly Charged Cylinder

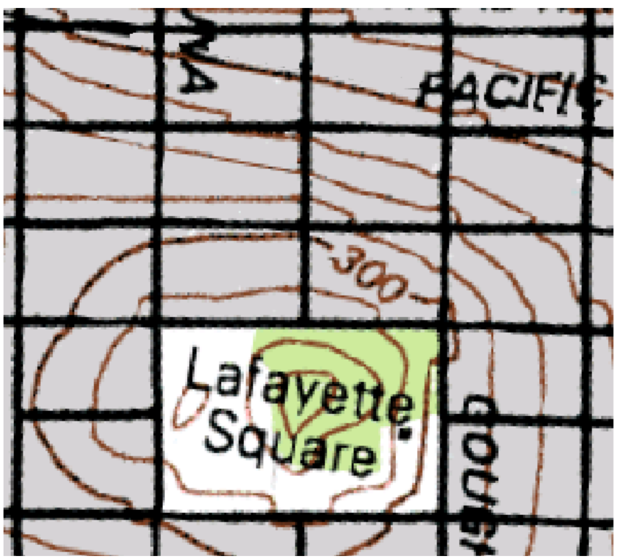
A cylindrical Plexiglas tube of length L, radius R carries a charge Q uniformly distributed over its surface. Find the electric field on the axis of the tube at one of its ends.

Expt. 1: Equipotential Lines and Electric Fields Pre-Lab Questions

In the weeks that you have a lab on Wednesday the problem set will also include pre-lab questions. These questions typically cover material which has **not** been covered in class. You will most likely find it helpful to do the pre-lab reading before attempting these questions.

Problem 6: Equipotentials Curves – Reading Topographic Maps

Below is a topographic map of a 0.4 mi square region of San Francisco. The contours shown are separated by heights of 25 feet (so from 375 feet to 175 feet above sea level for the region shown)



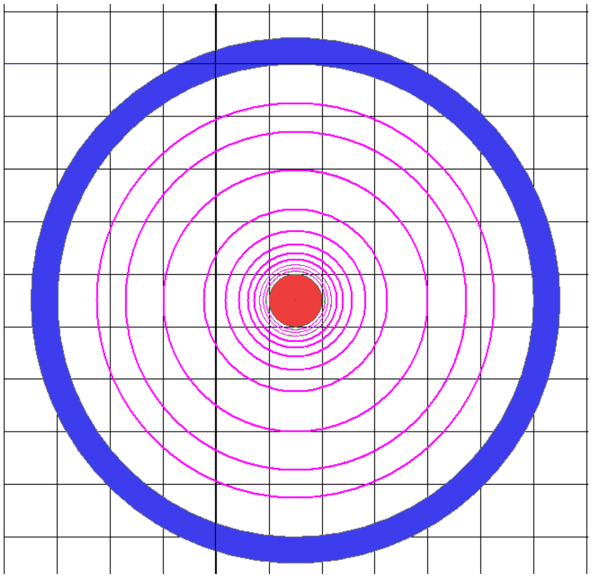
From left to right, the NS streets shown are Buchanan, Laguna, Octavia, Gough and Franklin. From top to bottom, the EW streets shown are Broadway, Pacific, Jackson, Washington, Clay (which stops on either side of the park) and Sacramento.

(a) In the part of town shown in the map at left, which street(s) have the steepest runs? Which have the most level sections? How do you know?

(b) How steep is the steepest street at its steepest (what is its slope in ft/mi)?

(c) Which would take more work (in the physics sense): walking 3 blocks south from Laguna and Jackson or 1 block west from Clay and Franklin?

Problem 7: Equipotentials, Electric Fields and Charge



One group did this lab and measured the equipotentials for a slightly different potential landscape then the ones you will be given (although still on a 1 cm grid) and using +10 V rather than +5V.

Note that they went a little overboard and marked equipotential curves (the magenta circles) at V = 0.25 V, 0.5V and then from V = 1 V to V = 10 V in 1 V increments.

They followed the convention that red was their positive electrode (V = +10 V) and blue was ground (V = 0 V).

(a) Copy the above figure and sketch eight electric field lines on it (equally spaced around the inner conductor).

(b) What, approximately, is the magnitude of the electric field at r = 1 cm, 2 cm, and 3 cm, where r is measured from the center of the inner conductor? You should express the field in V/cm. (HINT: The field is the local slope (derivative) of the potential. Also, if you choose to use a ruler realize that the above reproduction of this group's results is not the same size as the original, where the grid size was 1 cm).

(c) What is the relationship between the density of the equipotential lines, the density of the electric field lines, and the strength of the electric field?