MIDTERMI 2 Tuesday November 5, 2013

Instructor: Prof. A. LANZARA

TOTAL POINTS: 100

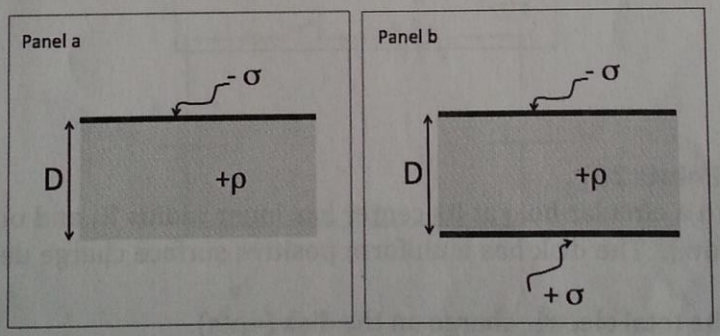
TOTAL PROBLEMS: 5

Show all work, and take particular care to explain what you are doing. Partial credits are given. Please use the symbols described in the problems, define any new symbol that you introduce and label any drawings that you make. If you get stuck, skip to the next problem and return to the difficult section later in the exam period.
All answers should be in terms of variables.

GOOD LUCK!

PROBLEM 1 (Points 20)

We have an infinite, non-conducting sheet of negligible thickness carrying a uniform surface charge density – σ and, next to it, an infinite parallel slab of thickness D with uniform volume charge density +ρ (see panel a). All charges are fixed.



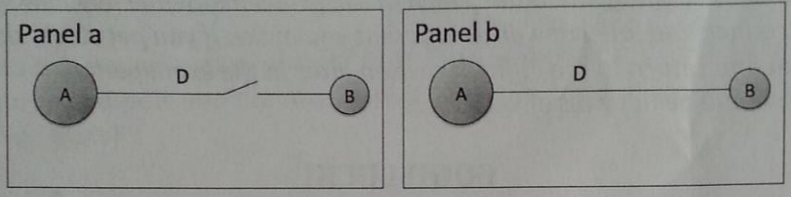
Calculate the direction and the magnitude of the electric field.

a) At a distance h above the negatively charged sheet (5 pts)
b) Inside the slab at distance d below the negatively charged sheet (d<D) (5pts)
c) At a distance H below the bottom of the slab. (5pts)
d) We now add a non-conducting sheet of uniform surface charge density +σ to the bottom of the slab (panel b). Calculate the direction and magnitude of the electric field inside and outside the slab (5pts)

PROBLEM 2 (Points 20)

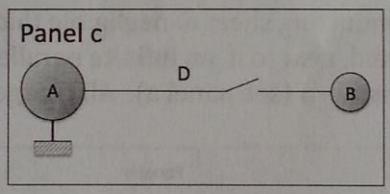
Consider two conducting metal spheres of radius R_A=30cm and R_B=10cm connected by a metallic wire (see panel a). The spheres are at a distance D=10R_A much bigger than their radius. The switch is initially open and sphere A has a net charge Q_A=2 x 10^{-8} C, while sphere B is neutral (panel a). We now close the switch (panel b).

a) What is the final charge that the spheres need to have to avoid any charge flowing between them? (10pts)



The two charged spheres will now repel each other with a repulsive force $\mathbf{F}_0$= 10^{-5} N. We now open the switch and connect sphere A to the ground (V=0) (panel c).

b) Find the magnitude and direction of the force **F** between the two spheres in this new condition. (10pts)



PROBLEM 3 (Points 20)

A thin disk with a circular hole at its center has inner radius R_1 and outer radius R_2 (see figure below). The disk has a uniform positive surface charge density σ on its surface.

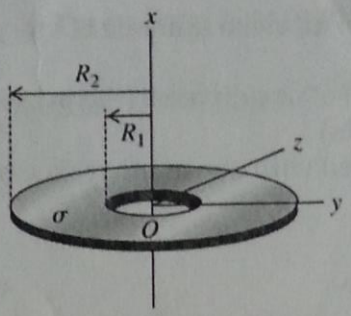
a) Determine the total electric charge on the disk (4pts).

b) The disk lies in the zy plane with its center at the origin. For an arbitrary point on the x-axis (the axis of the disc), find the electric potential. Consider points both above and below the disc in the figure (6pts).

c) Show that at points on the x-axis that are sufficiently close to the origin, the electric potential is approximately proportional to the distance squared between the center of the disc and the point. (5pts)

d) A point particle with mass m and negative charge –q is free to move along the x-axis (but cannot move off the axis). The particle is originally at rest at x=0.01 R_1 and released. Find the frequency of oscillation of the particle (5pts).

(Note: For an harmonic motion the frequency of oscillation is given by ω=sqrt(k/m))



PROBLEM 4 (Points 20)

Consider the circuit shown below that contains capacitors C_1 and C_2 and resistor R. Initially the switch is open and capacitor C_1 has charge Q_0. The switch is closed at t=0.

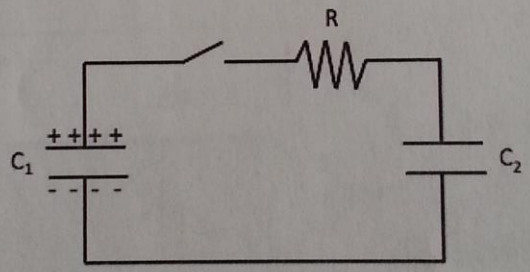
a) What is the initial current that flows through the resistor right after the switch is closed? (4pts)

b) After a very long time, what are the charges Q_1 and Q_2 on C_1 and C_2 respectively? (4pts)

c) What is the charge Q_2 (t) on C_2 as a function of time? (5pts)

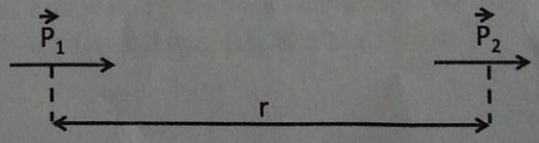
d) What is the current flowing into C_2 as a function of time? (4pts)

e) How will $Q_2(t)$ be modified if a dielectric of constant ε is inserted in between the plates of capacitor C_2? (3pts)

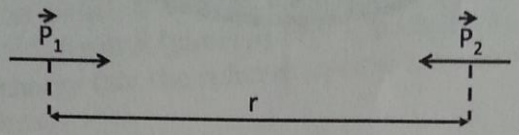


PROBLEM 5 (Points 20)

Two electric dipoles with dipole moments p_1 and p_2 are in line with one another as shown below. Assume the distance *r* between the dipoles is much greater than the length *d* of either dipole.



a) Find the electric field due to an electric dipole at any position on the axis of the dipole. (8pts)
b) Find the potential energy U of one dipole in the presence of the other dipole (i.e. their interaction energy). (3pts)
c) If the dipoles are anti-aligned with one another (see below), what is U? (3pts)



d) Now assume we turn on an electric field E_0 as shown below. Describe what happens to each dipole and find the maximum torque that the field can exert on each dipole. (6pts)