Massachusetts Institute of Technology ***Spring Term 2005***

Practice Quiz #1b

The quiz has four questions. It is a closed book quiz. No calculators are allowed.
A letter-size formula sheet can be used, but has to be signed and submitted together with the quiz.

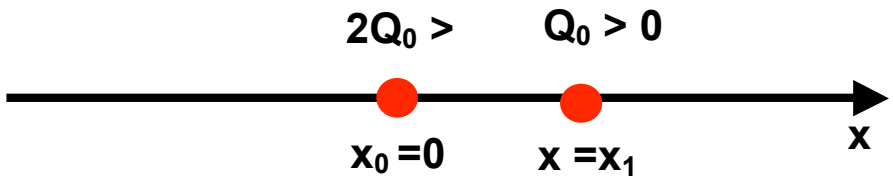
Problem 1 (25 points)

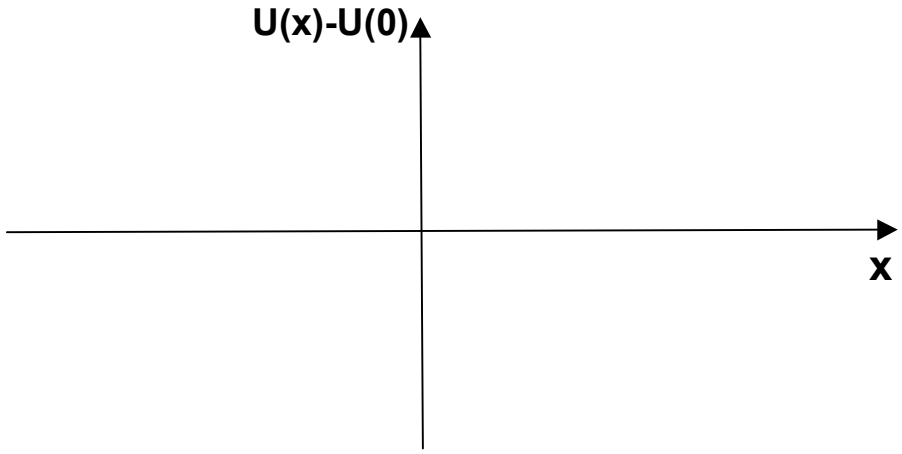
This problem deals with 3 positive charges, Q_0, $2Q_0$ and $3Q_0$. Consider the configuration shown below, with a $+2Q_0$ at position $x_0=0$ and a positive charge Q_0 at position x_1 along the x-axis.

(a) Find a position x_2 where the third positive charge $Q_3 = 3Q_0$ could be added, such that the total force on Q_3 is 0?

(b) Suppose Q_3 was moved a small distance Dx to the right (towards positive x) and then released from rest. What would the subsequent motion of Q_3 be?

(c) Qualitatively, describe what would happen if Q_0 was displaced by a small distance Δx from $x_0=0$ to $x=\Delta x$ and then released (two sentences max.)?





Problem 2 (25 points)

Consider the sequence of events (1) to (4) shown below. We start with 2 neutral conducting spheres that touch each other, but are insulated from the rest of the world (1). Then a positively charged rod is brought close to sphere 1, while sphere 1 and sphere 2 still touch. The rod does not touch the spheres(2). In the next step, the spheres are separated (3). Finally, the charged rod is removed (4).

(a) For each of the 4 steps, sketch the charge distribution on the spheres on the pictures below.

(b) After the rod has been removed (step (4)), consider the charges Q_1 on sphere 1 and Q_2 on sphere 2. Which of the following statements is true:

(i) $Q_1 = Q_2 = 0$

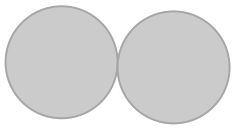
(ii) $|Q_1| > |Q_2|$

(iii) $|Q_2| < |Q_1|$

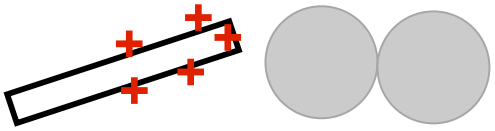
(iv) $Q_1 = -Q_2$, $Q_1 < 0$

(v) $Q_1 = -Q_2$, $Q_1 > 0$

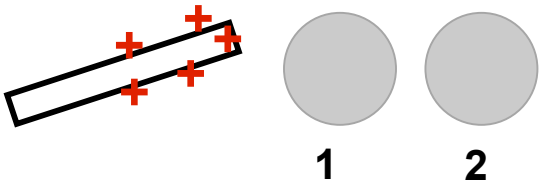
(1)



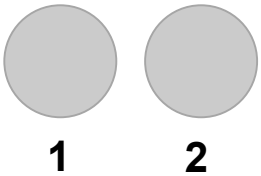
(2)



(3)



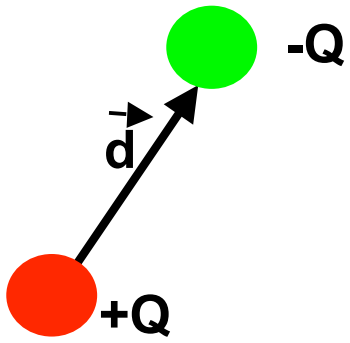
(4)



Problem 3 (25 points)

Shown below is an electric dipole with equal charges +Q and –Q separated by a distance d. The dipole is free to rotate or move. Consider the following information: The dipole sits inside an electric field with |E| > 0. The dipole does not feel a net torque. The dipole does not feel a net force. When rotated from its original orientation and released, the dipole moves back towards the original orientation.

(a) On the picture below, sketch field lines corresponding to an electric field that is compatible with this description.
(b) Qualitatively, describe what would happen if the positive charge +Q was doubled, while keeping the negative charge the same (two sentences max.)?



Problem 4 (25 points)

Shown below is a thin conducting spherical shell of radius r_0, carrying a total charge $Q > 0$ (the thickness of the shell can be neglected).

(a) Find the electric field E(r) created by the charged shell as a function of r, where r is the distance to the center of the shell. Determine E(r) both for $r < r_0$ and for $r > r_0$

(b) Determine the corresponding electric potential V(r) as a function of r, relative to V(r=0) = 0.

(c) On the graph below, sketch the potential energy U(r) for a negative point-charge $q_0 < 0$ in the field created by the shell.