Name: _____ Student ID: _____

PHYS 3033 Electricity and Magnetism I

Quiz 4

29 September 2015

Time allowed 20 minutes

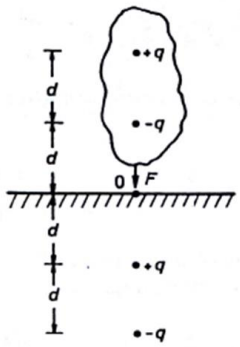
Method of Image Charges

When a cloud passes over a certain spot ('point 0') on the surface of the earth a **vertical** electric field of E = 100 V/m is recorded here. The bottom of the cloud is a height d = 300 m above the earth and the top of the cloud is at hight d = 300 m above the bottom. Assume that the cloud is electrically neutral but has charge $+q$ at its top and charge $-q$ at its bottom (you may treat them as two point charges, arranged vertically in-line with point 0!). Please assume that there are no charges in the atmosphere other than those on the cloud.

a) Prepare a sketch of the charge configuration above the ground, as well as of the induced image charges below the ground.
b) Write down the expression of the total electric field at point 0.
c) Calculate the magnitude of the charge q.
d) Calculate the external electrical force (direction and magnitude) on the cloud.

Solutions

a) The positions of the image charges are shown in the figure below.



b) The electric field intensity at point 0 on the surface of the earth is
$E = 2\frac{1}{4\pi\epsilon_0}\frac{q}{d^2} - 2\frac{1}{4\pi\epsilon_0}\frac{q}{4d^2}$.

c) We get
$q = \frac{8\pi\epsilon_0 d^2 E}{3} = 6.7 \times 10^{-4} C$.

d) The external force acting on the cloud is the electrostatic force between the image charges and the charges in the cloud, i.e.,
$F = \frac{q^2}{4\pi\epsilon_0}\left[-\frac{1}{4d^2} + \frac{1}{9d^2} + \frac{1}{9d^2} - \frac{1}{16d^2}\right] = \frac{q^2}{4\pi\epsilon_0 d^2}\left[\frac{2}{9} - \frac{1}{4} - \frac{1}{16}\right] = -4.05 \times 10^{-3} N$.
The force is attractive.