IIIT-H

VIRTUAL LABS

Manual for Electrostatic Field II

(Electrostatic Fields for surface charge, volume charge)

Introduction:

In this experiment we will continue to evaluate electric fields for surface (ρ_s C/m^2) and volume charges (ρ_v C/m^3).

Objectives:

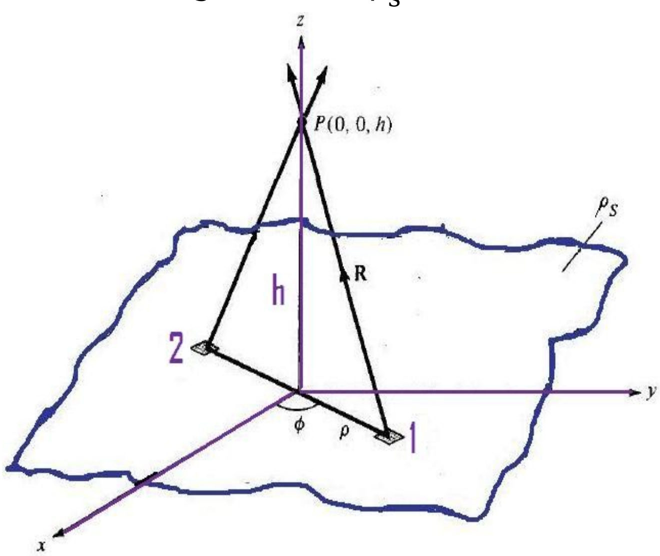
The main objectives of this experiment are the following:

1. To measure the electric field due to a infinite surface charge at any point in the space. Plot the graph of electric field as a function of distance and surface charge density.
2. To measure the electric field due to a uniformly distributed volume charge at any point in the space. Plot the graph of electric field as a function of distance and volume charge density.
3. To measure the electric field due to a spherical conductor. Plot the graph of electric field as a function of distance. Observe the difference between the plots of volume charge. Also observe the distribution of electric field as a function of distance

Theory:

1. Electric field due to a Surface Charge:

   Consider an infinite sheet of charge in the xy-plane with uniform charge density ρ_s. The charge associated with an elemental area dS is
   $dQ = \rho_s\, dS$
   So the total charge is $Q = \int \rho_s\, dS$



   Thus the contribution to the E at point P(0,0,h) by the elemental surface is

$dE = dQ\, a_R/4\pi\varepsilon_0 R^2$.

$R = \rho(-a_\rho)+ha_z$, $R= |R| = [\rho^2 + h^2]^{1/2}$

$a_R= R/R$,$dQ = \rho_s dS = \rho_s \rho\, d\varphi\, d\rho$

$E= \int dE_z$

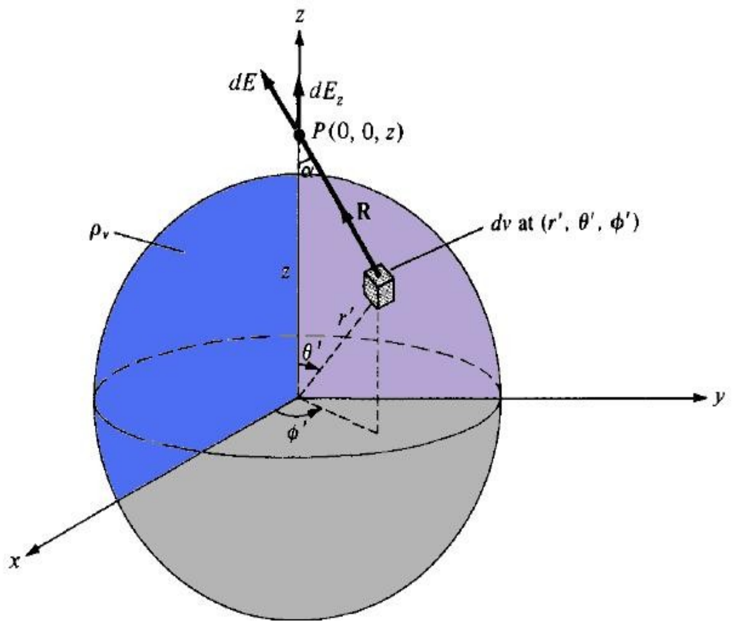
$E = \rho_s a_z/2\varepsilon_0$

This is only z-component of Electric field if the charge is in x-y plane. For infinite sheet of charge
$E = \rho_s a_n/2\varepsilon_0$

For a parallel plate capacitor $E= \rho_s a_n/\varepsilon_0$.

2. <u>Electric field due to Volume Charge Distribution</u>

Let the volume charge distribution with uniform charge density ρ_v, So charge dQ associated with the elemental volume dv is
$dQ = \rho_v dv$



The total charge in a sphere of radius 'a' is

$Q = \int \rho_v dv = \rho_v \int v$

$Q = \rho_v\, 4\pi\, a^3/3$;

The Electric field at point (0,0,z) is
$dE = \rho_v dv a_R/4\pi\varepsilon_0 R^2$

$a_R = \cos\alpha\, a_z + \sin\alpha\, a_\rho$.Due to symmetry of charge distribution we have $E_x + E_y = 0$.

$E_z = \int dE\cos\alpha = (\rho_v)/4\pi\varepsilon_0 \int dv \cos\alpha/R^2$
$dv = r'^2 \sin\theta' dr' d\theta' d\varphi'$
$R' = z^2 + r'^2 - 2zr'\cos\theta'$
$r' = z^2 + R^2 - 2zR\cos\alpha$

using all the substitutions and solving the integration the electric field at (0,0,z) is:
$E_z = E = Qa_z/ 4\pi\varepsilon_0 z^2$

Due to the symmetry of the charge distribution, the electric field at (0,0,z) is readily obtained from
$E= Q/4\pi\varepsilon_0 r^2$ which is identical to the electric field at the same point due to a point charge Q located at the origin or the center of the spherical charge distribution.

2. <u>Electric field in a conductor :</u>

In case of conductor charge resides only on the surface of it. Charge inside the conductor is zero. Hence Electric field inside the conductor is zero. Outside the conductor the charge acts as a point charge placed at the centre of the conductor.

We will learn more about the Electric field in conductors in the next experiment.

<u>Procedure:</u>

This experiment consists of 3 parts. Each part depicts the electric field of the charge distribution considered. Changing the sliders, you can see the change in E field. Also the corresponding values related to these are shown in the panel just above the sliders. Also the graphs related to each experiment are shown in the right panel.
In each of the experiments observe the symmetric field surfaces (the surface over which the electric field would be equal) formed by each of the distributions.

Start the experiment by pressing *start* button

- **<u>Part 1</u>** :
    1. In this stage we observe the behavior of electric field due to an infinite sheet.
    2. Measure the change in electric field at any point when surface

charge density changes .This can be observed by manipulating the sliders provided.

3. An animation is shown in this experiment on how the electric field is behaving at each point in the space.
4. Observe carefully and see how electric field due to the infinite sheet is dependent on the distance r.

- **Part 2**:
  1. In this stage we observe the behaviour of electric field due to a conductor.
  2. When the charge density of the volume charge increases measure how magnitude of electric field varies.This can be observed by manipulating the sliders provided.
  3. Observe electric field inside the conductor. See where, the charge is residing on sphere (is shown in experiment by + signs on the surface of conducting sphere.)
  4. The conducting sphere behaves similar to point charge, except for one difference. This difference can be seen from the graphs shown in right side of window.

- **Part 3**:
  1. In this stage we observe the behavior of electric field due to a Volume Charge.
  2. When the charge density of the conducting charge increases the magnitude of electric field has to be measured. This can be observed by manipulating the sliders provided.
  3. Observe the electric field inside the volume charge, and compare with that of Conductor. Charge of conducting sphere is present only on the surface, but what about the volume charge.
  4. Inside volume charge, measure how E is related to distance of point from center of volume charge. Outside the volume charge, measure how electric field is related to distance (same as for conductor). This difference can be seen from the graphs shown in right side of window.