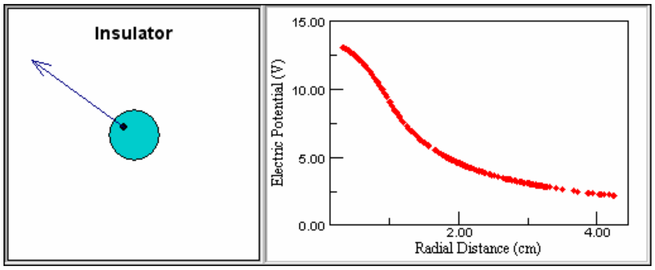
Worksheet for Exploration 25.5: Spherical Conductor and Insulator



How does the electric potential around a charged solid insulating sphere (with charge distributed throughout the volume of the sphere) compare with the electric potential around a charged conducting sphere? Move the test charge to map out the electric potential as a function of distance from the center **(position is given in centimeters and electric potential is give in volts)**.

a. Why is the voltage constant inside the conductor?
   i. Your discussion should include consideration of electric field or forces, and work or energy.

b. Why is there no electric field and no force on the test charge inside the conductor?
   i. Is this true for only a spherical conductor? Your answer should include other geometries.

c. Looking at the plots you make of voltage as a function of radial distance (as you move the test charge), what is the same and what is different between the two cases? Given that both spheres have the same total charge, explain the similarities and differences in the plots.

d. The electric field outside both spheres is $Q/4\pi\varepsilon_0 r^2$. Using this and the reference point of V = 0 Volts at infinity, find an expression for the potential at a point outside the sphere and a distance r from the center of the sphere. $V = -\int \mathbf{E(r')} \bullet d\mathbf{r'}$ and integrate from r = infinity (where V = 0 Volts) to a point r.
   i. Note that the primed r's indicate a variable for purposes of integration, where r is a specific limit position for purposes of the integration.

e. Measure the voltage at some point outside the sphere and find the charge on both spheres. Verify that the total charge is the same.

Conductor

$r=$__________ $V_{measured}=$__________ $V_{theory}=$_________

Insulator

$r=$__________ $V_{measured}=$__________ $V_{theory}=$_________

Now for the voltage inside the uniformly charged insulator. Here the electric field is $Qr/(4\pi\varepsilon_0 R^3)$ where R is the radius of the sphere itself. In this case, to find the electric potential as a function of r, you again need to integrate $V = -\int \mathbf{E} \cdot d\mathbf{r}$, but this time you must break up the integral and integrate from infinity to R using $E = Q/4\pi\,\varepsilon_0 r^2$ (to find the electric potential associated with getting all the charges to the surface of the sphere) and then integrate from R to r (an arbitrary point inside the sphere) using the expression for the electric field inside the insulating sphere.

f. Verify that your calculation gives the same results as shown on the graph. (for an R inside the surface of the insulator)

Insulator

$r=$__________ $V_{measured}=$__________ $V_{theory}=$_________

Additional Question

Consider the insulator. The charge was uniformly distributed throughout the volume. Qualitatively discuss how things would change if the density changed as a function of r. This is similar to the Earth where the mass density varies as one moves from the crust to the core (*not that anyone can do that …except in some science fiction movies*).