

PHYS102 Quiz - Solution Set

Department of Physics

Spring 2017 - May 16, 2017

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Questions:

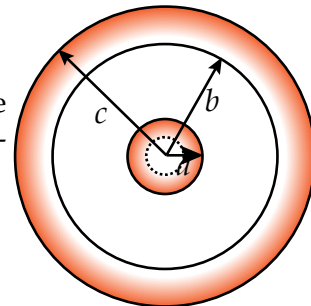
A solid conducting sphere of radius $a = 1\text{cm}$ has a charge $q_1 = 3\mu\text{C}$. Concentric with this sphere is a charged conducting shell with inner radius $b = 3\text{cm}$ and outer radius $c = 4\text{cm}$ having a charge $q_2 = -5\mu\text{C}$.

- a) Calculate the electric field in the regions $r < a$.

Solution:

As the sphere is conducting all the charges are on the surface of the sphere, so the enclosed charge is 0. So, the electric field inside the conducting sphere is:

$$\vec{E} = 0 \text{ for } r < a$$



- b) Calculate the electric field in the regions $a < r < b$.

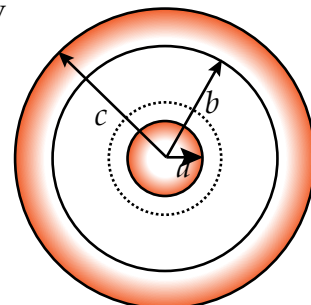
Solution:

The Gaussian surface encloses the charge $q_1 = 3\mu\text{C}$. So, we get by application of Gauss's Law

$$\oint \vec{E} \cdot d\vec{A} = \oint E \cdot dA = E \oint dA = E4\pi r^2 = \frac{q_{encl}}{\epsilon_0} = \frac{q_1}{\epsilon_0}$$

Solving this equation for the electric field:

$$\vec{E} = \frac{1}{4\pi\epsilon_0} \frac{q_1}{r^2} \hat{r} = 9 \times 10^9 \frac{\text{Nm}^2}{\text{C}^2} \frac{3 \times 10^{-6}\text{C}}{r^2} \hat{r} = 2.7 \times 10^4 \frac{\text{Nm}^2}{\text{C}} \frac{\hat{r}}{r^2}$$

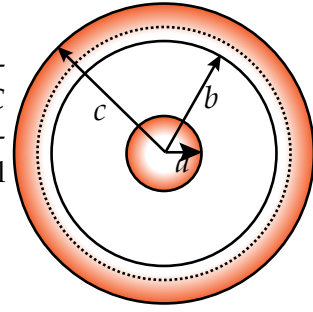


- c) Calculate the electric field in the regions $b < r < c$.

Solution:

As the shell is conducting all the charges are on the surface of the conducting shell. The charge q_1 induces a charge $q_{ind1} = -q_1 = -3\mu\text{C}$ on the inner surface of the shell. So, the charge enclosed by the Gaussian surface is 0 and the electric field inside the conducting shell becomes:

$$\vec{E} = 0 \text{ for } b < r < c$$



- d) Calculate the electric field in the regions $r > c$.

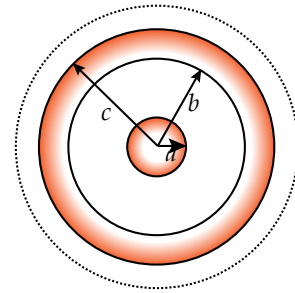
Solution:

The Gaussian surface encloses the charge $q_1 + q_2 = 3\mu\text{C} - 5\mu\text{C} = -2\mu\text{C}$. So, we get by application of Gauss's Law

$$\oint \vec{E} \cdot d\vec{A} = \oint E \cdot dA = E \oint dA = E4\pi r^2 = \frac{q_{encl}}{\epsilon_0} = \frac{q_1 + q_2}{\epsilon_0}$$

Solving this equation for the electric field:

$$\vec{E} = \frac{1}{4\pi\epsilon_0} \frac{q_1 + q_2}{r^2} \hat{r} = 9 \times 10^9 \frac{\text{Nm}^2}{\text{C}^2} \frac{-2 \times 10^{-6}\text{C}}{r^2} \hat{r} = -1.8 \times 10^4 \frac{\text{Nm}^2}{\text{C}} \frac{\hat{r}}{r^2}$$



- e) Calculate the potential difference $\Delta V_{ab} = V(b) - V(a)$.

Solution:

The electric field in the region from a to b is given according to question b) as:

$$\vec{E} = \frac{1}{4\pi\epsilon_0} \frac{q_1}{r^2} \hat{r}$$

So, the electric potential can be determined as:

$$\begin{aligned} \Delta V_{ab} &= - \int_a^b \vec{E} \cdot d\vec{\ell} = - \int_a^b \frac{1}{4\pi\epsilon_0} \frac{q_1}{r^2} \hat{r} \cdot \hat{r} d\vec{r} = - \frac{q_1}{4\pi\epsilon_0} \int_a^b \frac{dr}{r^2} = k_e \left(\frac{q_1}{b} - \frac{q_1}{a} \right) = \\ &= 9 \times 10^9 \frac{\text{Nm}^2}{\text{C}^2} \left(\frac{3 \times 10^{-6}\text{C}}{0.04\text{m}} - \frac{3 \times 10^{-6}\text{C}}{0.03\text{m}} \right) = -2.25 \times 10^5 \text{V} \end{aligned}$$