CONDUCTING CONCENTRIC THIN SPHERICAL SHELLS, AND DISTRIBUTION OF CHARGE

Conducting concentric thin spherical shells:

Conducting concentric thin spherical shells refer to a configuration of spherical shells made of conductive material that are nested within each other, sharing the same center. These shells are characterized by their thinness, meaning that their thickness is negligible compared to their radii. The term "conducting" indicates that these shells are capable of conducting electricity, allowing electric charges to move freely along their surfaces. The shells are arranged in such a way that they have a common center point and are aligned one inside the other, forming a series of nested spheres. This configuration is often encountered in problems related to electrostatics and electromagnetic theory, where the behavior of electric fields and charges within such arrangements is analyzed.

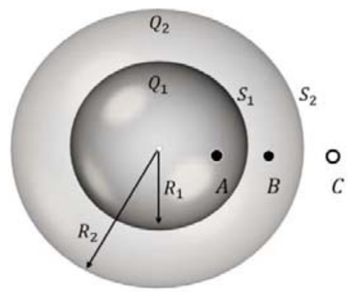
Distribution of charge:

The distribution of charge refers to how electric charge is spread or arranged within a given region or object. In the context of conducting concentric thin spherical shells, the distribution of charge may vary depending on factors such as the presence of external charges or the arrangement of multiple shells. When a charge is introduced into or onto such a system, it may distribute itself across the surfaces of the shells in response to electrostatic forces. This distribution of charge plays a crucial role in determining various electrical properties of the system, such as electric potential and electric field strength.

Conducting Concentric Thin Spherical Shells, And Distribution of Charge:

For a conducting shell with charge Q and radius R, the electric field inside the shell (r>R) is E_{in}=0, while outside the shell (r>R) it is given by $E_{out}=\frac{kQ}{r^2}$.

Considering two concentric shells, the electric field at various points is as follows:



Electric field:

At point $A: E_A = 0$

At point B: $E_B = \frac{K\theta_1}{\gamma^2} + 0$

At point $C: E = \frac{KQ_1}{r^2} + \frac{KQ_2}{\gamma^2}$

The potential at different points is:

At point $A: V_A = \frac{K\theta_1}{R_1} + \frac{K\theta_2}{R_2}$

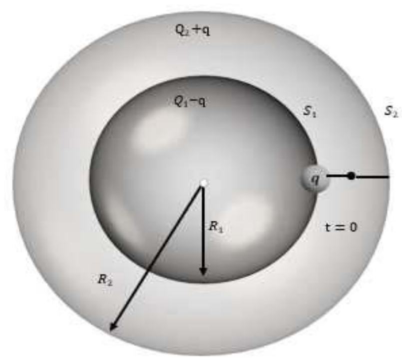
At point $B: V_B = \frac{K\theta_1}{\gamma} + \frac{K\theta_2}{R_2}$

At point $C: V_C = \frac{K\theta_1}{\gamma} + \frac{K\theta_2}{\gamma}$.

Potential on the surface $S_1: V_{S_1} = \frac{KQ_1}{R_1} + \frac{KQ_2}{R_2}$

Potential on the surface $S_2: V_{S_2} = \frac{KQ_1}{R_2} + \frac{KQ_2}{R_2}$.

When two concentric hollow spheres are interconnected by a wire, all the charge originally present on the inner sphere transfers to the outer sphere. In this configuration, both spheres effectively function as a single conductor. Consequently, the potential on both spheres becomes identical, denoted by $V_{s_1} = V_{s_2}$.



Mathematically, this can be expressed as:

$$\frac{K(Q_1 - q)}{R_1} + \frac{K(Q_2 2(q)}{R_2} = \frac{K(Q_1 - \varepsilon)}{R_2} + \frac{K(Q_2 q)}{R_2}$$

Solving this equation leads to:

$$R_2Q_1 - R_2q = R_1Q_1 - R_1q$$

Which simplifies to:

$$Q_1(R_2 - R_1) = q(R_2 - R_1)$$

Resulting in:

$$q = Q_1.$$

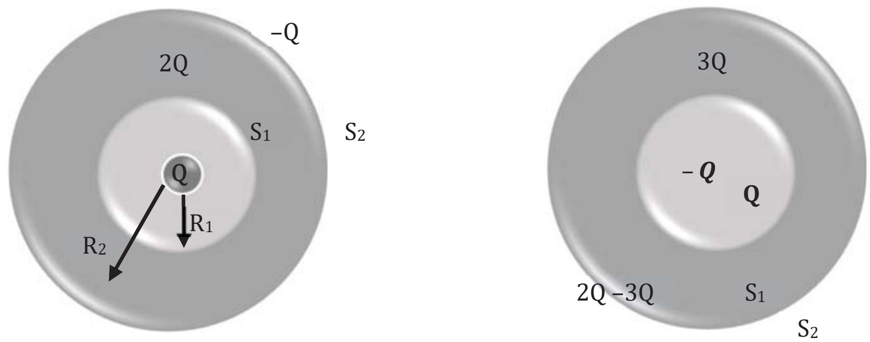
This indicates that all the charge from the inner sphere (Q_1) transfers to the outer sphere. In colloquial terms, when we connect the inner conductor to the outer conductor, it essentially becomes a single conductor. Moreover, all the charge migrates to the outer surface.

Initially, the outer shell possesses a negative charge of −Q, while the inner shell holds a positive charge of 2Q. Inside the inner shell, a positive charge +Q is introduced.

According to the principle of induction, placing a charge inside a hollow conductor causes opposite charge to be induced on its inner surface, with an equal amount of charge induced on its outer surface. As a result, a negative charge of −Q is induced on the inner surface of the inner shell, while a positive charge of +Q is induced on its outer surface due to the presence of the +Q charge inside the inner shell.

Consequently, the total charge on the inner surface of the inner shell (S_1) is −Q, and the total charge on its outer surface (S_2) is the sum of 2Q and Q, resulting in 3Q.

It follows that the surfaces of concentric spherical shells facing each other must exhibit equal and opposite charges.



The surfaces of concentric spherical shells that face each other are required to possess equal and opposite charges.

As the outer surface of S_1 carries a charge of +3Q, the inner surface of the outer shell (S_2) will induce a charge of −3Q, while its outer surface will carry a charge of +3Q.

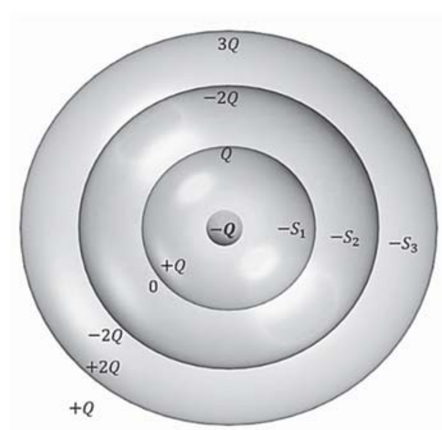
Consequently, the total charge on the inner surface of the outer shell (S_2) is −3Q, and the total charge on its outer surface is the sum of −Q and +3Q, resulting in 2Q.

The potential on S_1 due to this configuration is as follows:

$$V_{S_1} = \frac{K\theta}{R_1} + \frac{k(30-0)}{R_1} + \frac{K(-30+\quad)}{R_2}.$$

Initially, the charges on the different shells are distributed as follows:

On S_1: Q on S_2: $-2Q$ On S_3: $3Q$



Subsequently, within the inner shell S_1, a charge of −Q is introduced. Consequently, the induced charge distribution on S_1 is as follows:

- On the inner surface of S_1: +Q
- On the outer surface of S_1: −Q

Thus, the total charge on S_1 is as follows:

- On inner surface of S_1: $+Q$
- On outer surface of S_1: $-Q + Q = 0$

Given that the surfaces of concentric spherical shells facing each other must exhibit equal and opposite charges, the charge distribution on S_2 and S_3 is as follows:

- On the inner surface of S_2: 0
- On the outer surface of S_2: $0 - 2Q = -2Q$
- On the inner surface of S_3: $+2Q$
- On the outer surface of S_3: $-2Q + 3Q = +Q$

Charge distribution on parallel conducting plates:

When referring to charge distribution on parallel conducting plates, it typically pertains to a setup involving two or more flat conducting surfaces placed in close proximity to each other. The term "parallel" indicates that these plates are aligned in a parallel manner, maintaining a constant separation distance between them.

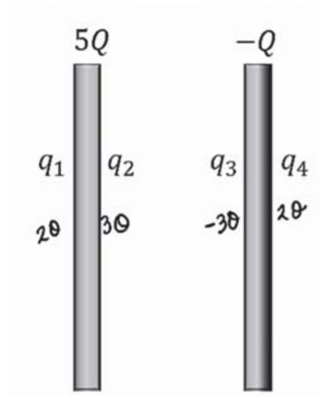
In such configurations, when an external voltage source is connected to the plates, charges redistribute themselves across the surfaces. Due to the conductive nature of the plates, charges can move freely within the material, resulting in an accumulation of charge on the surfaces facing each other.

The distribution of charge on the plates depends on various factors such as the applied voltage, plate geometry, and boundary conditions. In equilibrium, the charges on the plates reach a stable configuration where the electric field between the plates balances the external applied field, resulting in a uniform charge density across the surface of each plate

Ex. Two extensive parallel conducting sheets, situated at a finite distance from each other, are charged with $5Q$ and $-Q$, respectively. Determine the charges present on all surfaces.

Sol. We know that, $q_1 = q_4 = \frac{Q_1+Q_2}{2} = \frac{5Q+(-Q)}{2} = 2Q$

$$q_2 = -q_3 = \frac{Q_1-Q_2}{2} = \frac{5Q-(-Q)}{2} = 3Q$$



Introduction to electric current:

Electric current is a fundamental concept in physics and electrical engineering, referring to the flow of electric charge through a conductor. It is measured in amperes (A) and represents the rate at which electric charge flows past a specific point in a circuit.

Electric current can flow through various mediums, including conductive materials such as metals and electrolytes. In a metallic conductor, electric current is typically carried by the movement of electrons, while in electrolytes, it involves the movement of ions.

The flow of electric current is driven by the presence of an electric potential difference, commonly referred to as voltage, across the conductor. When a voltage is applied to a circuit, it creates an electric field that exerts a force on charged particles, causing them to move and thus generating electric current.

Electric current plays a crucial role in powering electrical devices, transmitting electrical signals, and performing various functions in electronic circuits.