ELECTROSTATIC SHIELDING AND EARTHLING OF CONDUCTORS

Electrostatic Shielding

Let's consider a conducting sphere containing a cavity. We denote the surfaces of the cavity and the outer surface of the sphere as S_1 and S_2 respectively.

Suppose we introduce a positive charge +Q into the cavity. As a result, negative charge −Q will be induced on the inner surface of the cavity, and positive charge +Q will be induced on the outer surface of the sphere.

Consequently, the total charge residing on the inner surface of the cavity is $Q_i = -Q$. Meanwhile, considering the initial charge $+Q_0$ on the outer surface of the sphere, the total charge on this surface becomes $(Q_0 + Q)$.

Considering the spherical nature of the cavity surface S_1, the charge Q_i will be uniformly distributed across the inner surface of S_1. As a result, the electric field at any point external to the surface S_1, induced by the total charge within the cavity (i.e., $Q_i + Q$), becomes nullified.

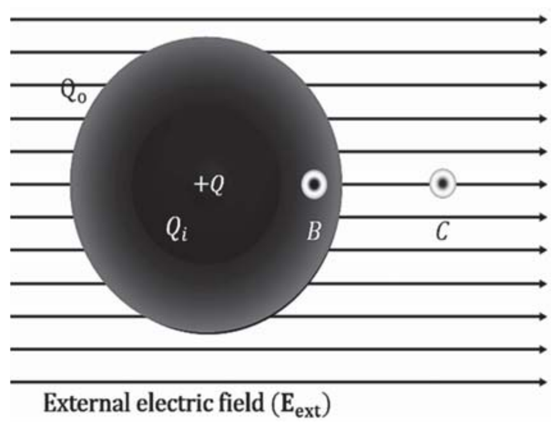
For cavities with arbitrary shapes, Q_i is distributed non-uniformly across the inner surface. However, it's arranged in a manner that ensures the electric field outside the cavity's surface, caused by the total charge within the cavity (i.e., $Q_i + Q$), remains zero.

As the sphere is conductive, within the material of the sphere (designated as point B), the electric field induced by the charge residing on the outer surface of the sphere is also zero.

The electric field at any point outside the sphere, exemplified by a point like C, originates solely from the charge residing on the outer surface of the sphere. Consequently, it can be concluded that the collective charge inside the cavity (i.e., Q_i+Q) holds no influence on the external environment surrounding the surface of the cavity.

Conversely, if a charge is positioned outside S_1, or if an external electric field is established, the charges within the cavity remain unaffected by their presence. This characteristic is referred to as "Electrostatic Shielding."

This property of a conductive cavity ensures that any charge or device situated inside the cavity remains isolated from external electric fields. It's akin to a car being shielded from lightning strikes. Therefore, during a lightning event, it's safer to decelerate the vehicle and remain inside rather than abandoning it.

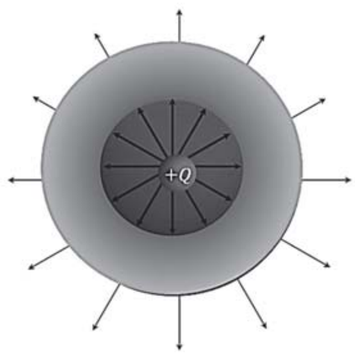


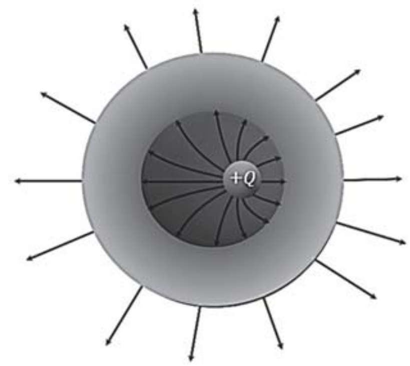
Considering point B lies within the material of the conductor, the resultant electric field at this point becomes null. Consequently, at point B, the sum of electric fields induced by the charges Q_i, and Q_0 equals zero, denoted as $E_Q + E_{Qi} + E_{Q0} = 0$.

Given that the electric field outside surface S_1 resulting from the total charge within the cavity (i.e., Q_i+Q) is zero, implying $E_Q + E_{Qi} = 0$, it follows that $E_{Q0} = 0$.

In practical terms, the charge Q_0 situated on the outer surface of the conducting sphere with a cavity adjusts its distribution to ensure that the electric field within S_2 originating from Q_0 remains null across all points.

If a conducting sphere with a cavity is positioned within an external electric field, the resultant electric field at point B is expressed as the sum of the electric fields induced by the charges Q, Q_i, Q_0, and the external field, denoted as $E_Q + E_{Qi} + E_{Q0} + E_{ext} = 0$.
Given that at point $E_Q+E_{Qi}=0$, it follows that $E_{Q0} + E_{ext} = 0$.
Hence, due to the influence of the external electric field, the charge Q_0 situated on the outer surface of the conducting sphere with a cavity adjusts its distribution to ensure that the collective electric field within S_2 originating from Q_0 alongside E_{ext} becomes zero. Importantly, the charge within the cavity remains unchanged despite the application of the external electric field.
When a charge Q is introduced into the cavity of the conductor, it induces a charge Q_i on the inner surface. This induction occurs in such a way that the combined effect of Q and Q_i results in a net electric field of zero at every point outside the inner surface of the conductor.
Similarly, if any charge is positioned outside the conductor or an external electric field is applied, the charge Q_0 on the outer surface adjusts its distribution to ensure that the electric field within the conductor, resulting from the combined effect of Q_0 and the external field, becomes zero across all points inside the outer surface.





A positive point charge denoted as +Q is placed precisely at the center of a spherical cavity.

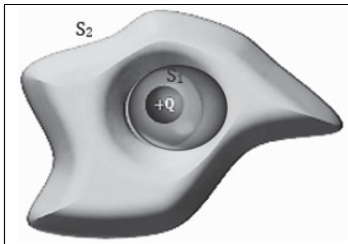
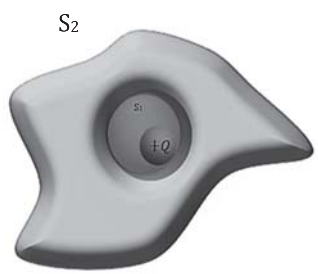
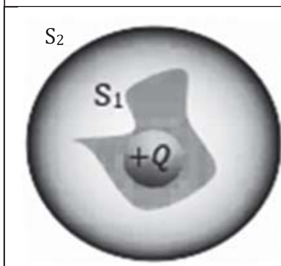
1. The negative charge −Q will be uniformly distributed across the inner surface of the cavity, as the cavity wall possesses a spherical shape.
2. Conversely, the positive charge +Q will be uniformly distributed across the outer surface of the conducting sphere.

A positive point charge denoted as +Q is positioned at any arbitrary location inside the spherical cavity of a spherical conductor.

1. The charge induced on the inner surface of the cavity must be arranged in a manner that cancels out the electric field outside the cavity surface. Consequently, the distribution of induced charge on the inner surface will be non-uniform, as it needs to counteract the external electric field effectively.
2. The positive charge +Q will uniformly distribute itself across the outer surface of the conducting sphere. Consequently, the distribution of charge on the outer surface remains constant.

Distribution of charge

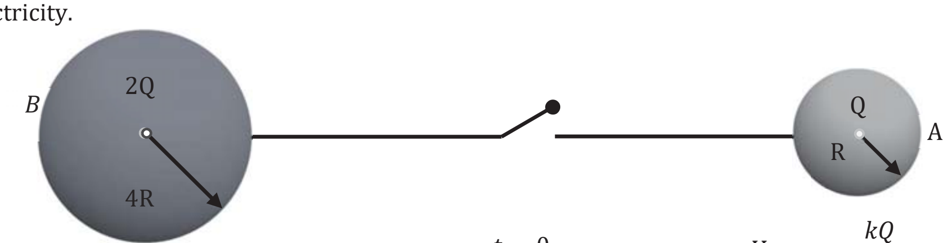
The distribution of charge refers to the arrangement or spread of electric charge within a given object or system. In a conductor, charges can redistribute themselves in response to external influences, such as the presence of nearby charged objects or electric fields. This redistribution of charge leads to changes in the electric field both within and around the conductor. Understanding the distribution of charge is essential in various fields, including electrostatics, electronics, and electrical engineering, as it affects the behavior and properties of electrical systems and components.

	The surface of the cavity, denoted as S_1, possesses a spherical shape. The outer surface of the conductor, represented by S_2, exhibits an arbitrary or non-specific shape.	A positive point charge denoted as +Q is positioned precisely at the central point within a spherical cavity.	The induced charge distribution on the surface S_1 is uniform, meaning it is evenly spread across the entire surface. The induced charge distribution on the surface S_2 is non-uniform, indicating that it is not evenly distributed across the surface and varies in magnitude or concentration at different points.
	The surface of the cavity, denoted as S_1, has a spherical shape. The outer surface of the conductor, referred to as S_2, exhibits an arbitrary shape, meaning it does not adhere to a specific or predetermined form.	A positive point charge, denoted as +Q, is placed at any location within the spherical cavity, excluding the central point.	The distribution of induced charge on surface S_1 is non-uniform, indicating that the charge is not evenly spread across the entire surface and varies in concentration at different points. Similarly, the distribution of induced charge on surface S_2 is also non-uniform, signifying that the charge is not uniformly distributed across the outer surface of the conductor and varies in intensity or density at different locations.
	The surface of the cavity, denoted as S_1, exhibits an arbitrary shape, meaning it does not adhere to a specific or predetermined form. The outer surface of the conductor,	A positive point charge, denoted as +Q, is placed at any arbitrary position within the cavity.	The distribution of induced charge on the surface S_1 is non-uniform, indicating that the charge is not evenly spread across the entire surface and varies in concentration at different points.

	referred to as S_2, has a spherical shape, indicating that it is rounded and symmetrical.		Conversely, the distribution of induced charge on the surface S_2 is uniform, implying that the charge is evenly distributed across the entire surface without variation in concentration.

Connecting or touching of conductor

Connecting or touching of a conductor refers to the physical contact established between two or more conductive materials or components. This contact allows for the flow of electric current between the conductors, enabling the transfer of electrical charge or signal transmission. Connecting conductors is a fundamental aspect of electrical circuits and systems, essential for completing circuits, establishing electrical pathways, and facilitating the transmission of electricity.

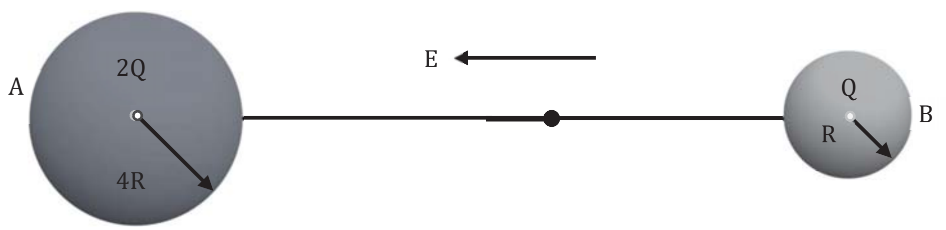


$t = 0$

$V_{initial_A} = \frac{kQ}{R}$

$V_{initial_B} = \frac{k(2Q)}{4R} = \frac{kQ}{2R}$

At time t = 0, when the conductors are not connected, the voltage at point B is lower than the voltage at point A.



When two conductors are connected or touched, an electric field is generated, flowing from the region of higher potential to the region of lower potential. Consequently, positive charge migrates from the area of higher potential to the area of lower potential until the potentials of both conductors equalize. It's important to note that the charges on the two conductors may or may not be equal during this process.

Thus, in this scenario, over time, positive charge denoted as +q moves from conductor B to conductor A, resulting in an equalization of their potentials.

Consequently,

$$(V_B)_{\text{final}} = (V_A)_{\text{final}}$$

$$\frac{k(Q-q)}{R} = \frac{K(2\theta+q)}{4R}$$

$$4\theta - 4q = 2\theta + q$$

$$\frac{2\theta}{5} = q$$

Hence, it follows that the final charge on conductor A, denoted as Q final (A), is equal to

$$\left[Q - \frac{2Q}{5}\right] = \frac{3Q}{5}.$$

Similarly, the final charge on conductor B, denoted as Q final(B), is calculated as

$$\left[2Q + \frac{2Q}{5}\right] = \frac{12Q}{5}$$

This example underscores the observation that despite both conductors attaining equal potentials, their charges differ.

Earthling of conductot

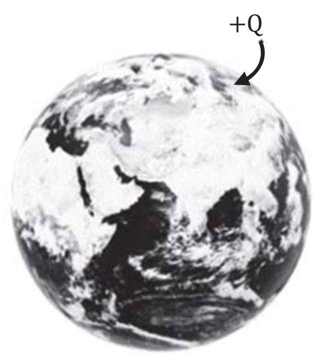
Earthing of a conductor refers to the process of connecting the conductor to the Earth or a large conducting body, typically through a conducting wire or rod buried in the ground. This connection to the Earth serves several purposes, including providing a reference point for electrical systems, stabilizing voltage levels, and facilitating the dissipation of excess electrical charge. By grounding conductors, electrical hazards such as electric shocks, equipment damage, and electrical fires can be prevented. Grounding is an essential safety measure in electrical systems, ensuring the proper functioning and protection of equipment and individuals.

When a conductor is connected to the Earth's surface, the potential of the Earth's surface is affected. For instance, if we place a positive charge +Q on the surface of the Earth, the electric potential on the Earth's surface is given by:

$$Ve = \frac{kQ}{Re}$$

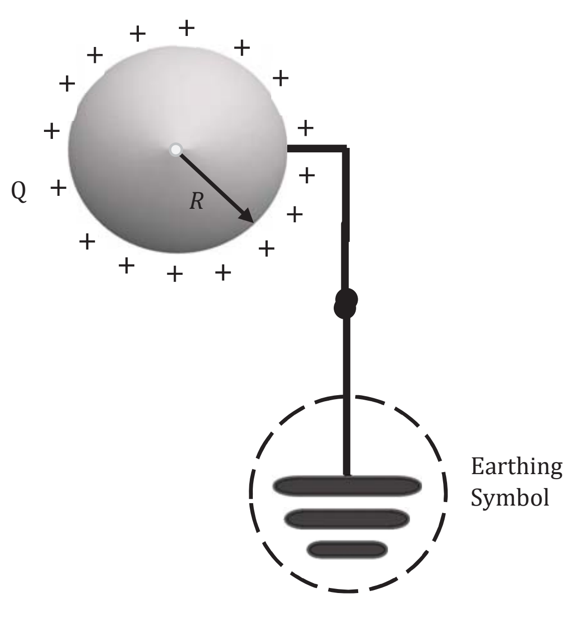
Considering that $R_e = 6400$ km is significantly large, the expression for the Earth's potential simplifies to approximately zero: $Ve \approx 0$

Hence, the potential of the Earth can be approximated as zero.



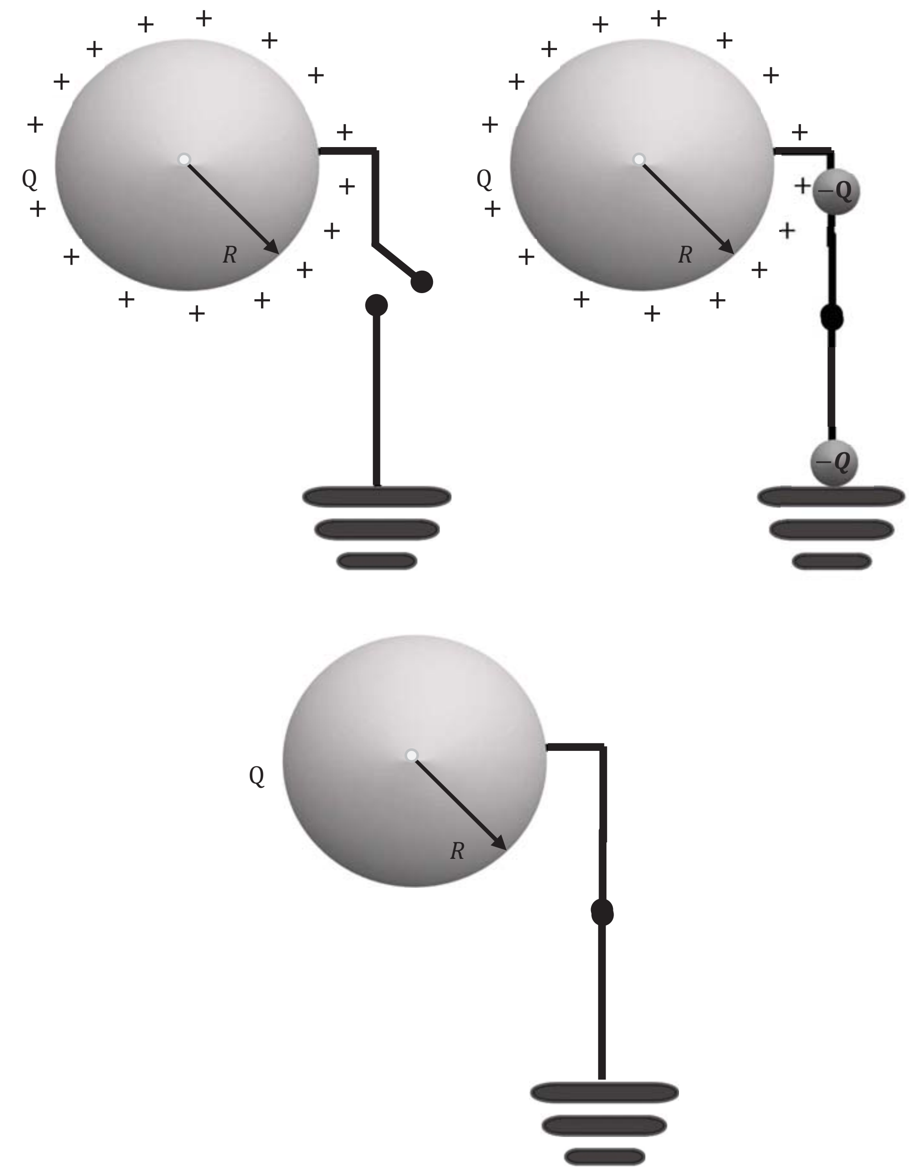
When an isolated spherical conductor, initially possessing a charge Q and a radius R, is connected to the Earth, a positive charge +q transfers from the conductor to the Earth. Considering the Earth as a conductor with a radius Re, both the conductor and the Earth reach an equilibrium where their potentials become equal.

Therefore,



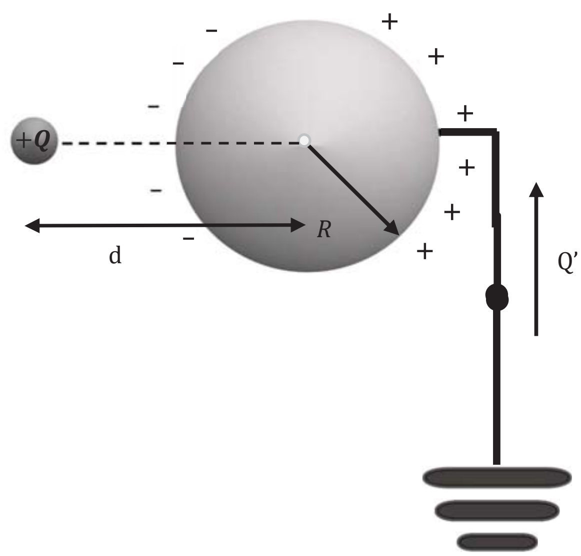
$$\frac{k(\theta - q)}{R} = \frac{kq}{R_e}$$
$$\theta - q = \frac{Rq}{R_e}$$
$$\theta = q[\frac{R + R_e}{R_e}]$$
$$q = [\frac{\theta R_e}{R + R_e}] = \frac{\theta}{1 + R_1/e_e}$$

Because Re is much greater than R, the ratio R/Re approaches zero.
Consequently, q approximates Q.
As a result, all charges from the conductor will transfer to the Earth.
When an isolated conductor comes into contact with the Earth, all of the charge residing on the conductor transfers to the Earth. The Earth, being an infinite reservoir and absorber of charges, accommodates the transferred charge. Consequently, when an isolated conductor connects with the Earth, the potential of the conductor diminishes to zero.



In this scenario, a positive charge +Q is positioned adjacent to an initially uncharged isolated conductor. Consequently, the system no longer remains isolated. When the conductor establishes a connection with the Earth, its potential tends toward zero. Let q′ represent the charge that flows from the Earth to the conductor.
Thus,

$$V_\theta + V_{q'} = 0$$
$$\frac{k\theta}{d} + \frac{k'}{R} = 0$$
$$q' = -\frac{R\theta}{d}$$



Earthing refers to the process by which the potential of a conductor is reduced to zero as a result of external charge interaction. However, whether the conductor itself becomes charged after earthing is uncertain; it may or may not retain a charge. Nonetheless, the likelihood of the conductor retaining a charge after earthing is essentially zero.