17.2: Shelding and Charging Through Induction

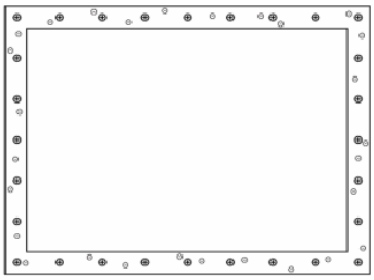
learning objectives

- Describe structure of a Faraday cage

Electrostatic shielding is the phenomenon that is observed when a Faraday cage operates to block the effects of an electric field. Such a cage can block the effects of an external field on its internal contents, or the effects of an internal field on the outside environment.

A Faraday cage is a closed chamber consisting of a conducting material or a mesh of such a material. This type of cage was first invented by Michael Faraday in 1836, and can block external static and non-static electric fields.

When an external electric field operates on a Faraday cage, the charges within the cage (which are mobile, as the cage is a conductor) rearrange themselves to directly counteract the field and thus "shield" the interior of the cage from the external field



Faraday Cage in Presence of an External Electrical Field: As the field is applied, the negative charge from the cage migrates toward the positive end of the field, canceling the effects of the field at both ends of the cage.

The action of a Faraday cage may depend on whether or not it is grounded. Consider a charge placed within a cage. If the cage is not grounded, electrons in the cage will redistribute such that the interior wall of the cage takes on a charge opposite the internal charge. This would leave an exterior wall of opposite charge to that of the interior. If it is grounded, however, excess charges on the exterior of the cage will go to the ground, leaving the exterior wall of neutral charge.

Limitations

Faraday cages are limited in their effectiveness, and cannot block static and slowly varying magnetic fields, such as that of the planet Earth. They can, however, shield the interior from external magnetic radiation provided that the mesh is smaller than the wavelength of the radiation and that the shield is sufficiently thick.

Applications

Microwave ovens contain energy within themselves, shielding the outside from harmful radiation.

Electrical linemen often wear suits made of Faraday cages so as to avoid electrocution.

Elevators can act as unintended Faraday cages, shielding cell phones and radios from signal from the outside.

Induced Charge

Electrostatic induction is the redistribution of charges within an object that occurs as a reaction to the presence of a nearby charge.

learning objectives

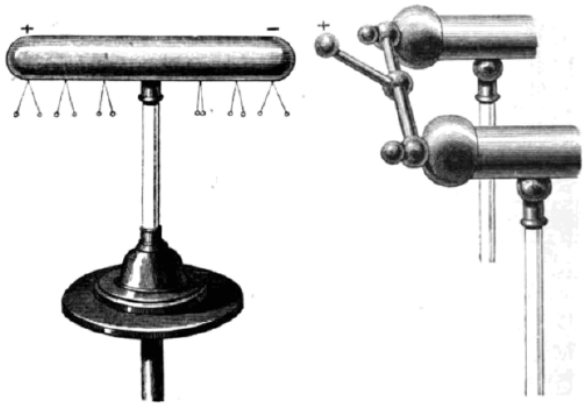
- Compare electrostatic induction processes in conductors and dielectrics

Electrostatic induction is the redistribution of charge within an object, which occurs as a reaction to a nearby charge.

Normally, a unit of matter will have equal parts positive and negative charge, distributed evenly throughout the object. As such, it has no net charge.

If a charged piece of matter is brought into close proximity with respect to an uncharged piece of matter, it can induce charge redistribution in the neutral material.

In such an event, the electrons in the neutral object move (the protons are relatively inert) according to the charge of the nearby charged object (inductor). If the inductor is positive, electrons migrate toward it, making the uncharged object more negative in that area and positive in the region opposite it. If the inductor is negative, the electrons in the neutral object are repelled, leaving a positive charge near the inductor and a negative charge opposite it.



Electric Induction Experiment: Circa 1870, the positive end of an electrostatic generator is placed near an uncharged brass cylinder, causing the cylinder to polarize as its left end becomes positive and its right end becomes negative.

If a charged object comes in touch with an uncharged object, or the two come sufficiently close to one another to cause a discharge that bridges the gap between them, the previously uncharged object will become charged. Depending on the sign of the charge of the inductor, electrons will go to or leave the previously uncharged object. Total charge is conserved, and that of the inductor decreases as it transfers charge to its subject.

Subjects that can react to inductors include conductors and dielectrics. In the case of the former, the free flow of charges makes it possible for strong polarization to occur. In the case of the latter, the force is comparatively weak.

Key Points

- Electrostatic shielding is the phenomenon that is observed when a Faraday cage operates to block the effects of an electric field. Such a cage can block the effects of an external field on its internal contents, or the effects of an internal field on the outside environment.
- A Faraday cage is a closed chamber consisting of a conducting material or a mesh of such a material. This type of cage can block external static and non-static electric fields.
- Faraday cages cannot block static and slowly varying magnetic fields, such as that of the planet Earth. They can, however, shield the interior from external magnetic radiation provided that the mesh is smaller than the wavelength of the radiation and that the shield is sufficiently thick.
- If a charged piece of matter is brought into close proximity with respect to an uncharged piece of matter, it can induce charge redistribution in the neutral material. This is one form of induction.
- If a charged object comes in touch with an uncharged object, or the two come sufficiently close to one another to cause a discharge that bridges the gap between them, the previously uncharged object will become charged. This is another form of induction.
- Subjects that can react to inductors include conductors and dielectrics. In the case of the former, the free flow of charges makes it possible for strong polarization to occur. In the case of the latter, the force is comparatively weak.

Key Terms

- **wavelength**: The length of a single cycle of a wave, as measured by the distance between one peak or trough of a wave and the next; it is often designated in physics as λ, and corresponds to the velocity of the wave divided by its frequency.
- **discharge**: the act of releasing an accumulated charge
- **inductor**: A passive device that introduces inductance into an electrical circuit.

- **dielectric**: An electrically insulating or nonconducting material considered for its electric susceptibility (i.e., its property of polarization when exposed to an external electric field).

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