Press or expanding force on a charged object located in a special zero electric field

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Abstract

In this paper, combining Newton's third law, the interaction conditions are analyzed for the system that a negative charged conductor ball is located inside a uniformly negative charged spherical shell. Under the premise of not violating Newton's third law, interesting phenomena are predicted. They are against current widely accepted recognition in electrostatics, such as a non-zero electric field exists in a charged conductor under the special electrostatic equilibrium.

Keywords: *charge distribution in conductor; electric field in conductor; electrostatic interaction.*

Introduction

It is well known to all of us that the electric field is zero inside a uniformly charged spherical shell [1, 2] and a static charge does not experience force in an area where the electric field is zero. In classical electromagnetism, any place with zero electric field is identical in electricity.

Analysis and discussion

Because the electric field is zero inside a uniformly charged spherical shell, it is generally considered that there is no any electric field force on a charged object which is placed in this area. However, on the other hand, the charged object produces a radial electric field and the charged spherical shell is in the electric field of the charged object. The electric field of the charged object is not zero at the place where the shell is, so, the charged shell experiences a force from the radial electric field of the charged object. Suppose the object is a spherical ball and the charges are uniformly distributed within the body of the ball, the force on the shell will be radially. With the fact that the electric field is zero inside the uniformly charged shell, there seem to be no electric force on the charged object. However, according the Newton's Third Law, a reaction force from the shell will act on the charged object. The reaction force has the same magnitude as the force on the charged shell but in opposite direction.

For the object, the force looks like a press or expanding force. When the charges of the shell and the object are like, the object will feel a press force and the shell will feel an expanding force. When the charges of them are opposite, the object will feel an expending force and the shell will feel a press force. The interactions are shown in figure1 and figure2. Following this logic, some interesting phenomena are predicted, which are against current widely accepted recognition in electrostatics, such as a non-zero electric field exists in a charged conductor under this special electrostatic equilibrium.

For example of the system in figure1, the object is a negatively charged conductor ball.

Because both the object and the shell are negatively charged, the reaction force from the shell will push the negative charges (electrons) towards to the center of the conductor ball, so that an electric field is established between the center and the edge inside the conductor ball, as shown in figure3. The created electric field drives the negative charges (electrons) to resist the reaction force from the shell. Under electrostatic equilibrium, the two forces are equal in magnitude.

In figure3, let's set $\mathbf{Q_c}$ is the electric quantity of the charged conductor ball, $\mathbf{Q_s}$ the electric quantity of the charged shell, $\mathbf{R_s}$ the radius of the shell, $\mathbf{R_c}$ the radius of the conductor ball. Thus, the total force on the shell by the electric field of the charge conductor ball is $\mathbf{Q_c Q_s} / \varepsilon_0 \mathbf{R}s^2$, so the total reaction force on the conductor ball is $\mathbf{Q_c Q_s} / \varepsilon_0 \mathbf{R}s^2$, too. We know that all the charges are uniformly distributed on the surface of a spherical charged conductor when it is free from any electric field. When the negatively charged conductor ball is placed inside the uniformly negatively charged spherical shell, it is reasonable to suppose that the negative charges (electrons) are pushed towards to center and suppressed on a spherical surface with radius of r (r < $\mathbf{R_c}$) inside the conductor ball. We set the established electric field strength on the spherical surface of r is $\mathbf{E}_r$ and the charge density on the surface is σ, thus, the total force of this electric field on the whole negative charges of the conductor ball will be $\mathbf{E}_r \sigma 4\pi r^2$. Under equilibrium, it should be equal to the total reaction force from the charged shell, so

$$\mathbf{E}_r \sigma 4\pi r^2 = \mathbf{Q_c Q_s} / \varepsilon_0 \mathbf{R}s^2 \qquad (1)$$

Under equilibrium state, $\sigma = \mathbf{Q_c} / 4\pi r^2$, So, (2)

$$\mathbf{E}_r = \mathbf{Q_s} / \varepsilon_0 \mathbf{R}s^2 \qquad (3)$$

From equation (3), we see that the established electric field strength on the surface of r inside the conductor ball is only decided by the charged spherical shell. It is proportional to the charge quantity of the shell and reversely proportional to the radius of the shell.

Conclusions

By detailed analyzing the system that a negative charged conductor ball is located inside a uniformly negatively charged spherical shell, under the premise of not violating Newton's third law, we get following conclusions:

1. The negative charges (electrons) of the conductor ball feel a reaction force from the charged shell and the negative charges (electrons) are pushed towards to center of the conductor.
2. An electric field is established in the body of the charged conductor ball, which drives the negative charges to resist the reaction force from the charged shell. Thus, an electrical potential difference is produced between the center and edge of the conductor.
3. The magnitude of this created electric field on the boundary of the negative charges in the body of conductor is only decided by the uniformly charged spherical shell. It is proportional to the charge quantity of the shell and inversely proportional to the radius of the shell.
4. A charged object, which is inside a uniformly charged spherical shell, feels press or expanding force due to the reaction force from the charged shell.
5. Based on the fact that press or expanding force experienced by a charged object, the zero electric field inside a uniformly charged spherical shell is not identical to a null electric field

region far away from any electric sources. It is more proper to call the former one relative zero electric field and the latter absolute zero electric field.

References

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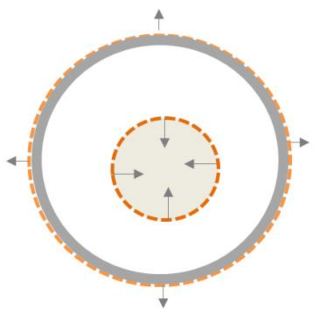


Fig.1. A negatively charged object is located inside a uniformly negatively charged spherical shell. The charged object feels a press force from the charged spherical shell. The arrows indicate the direction of force

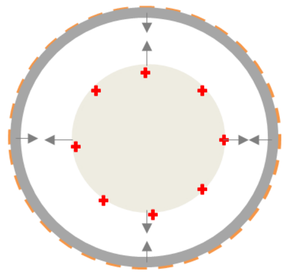
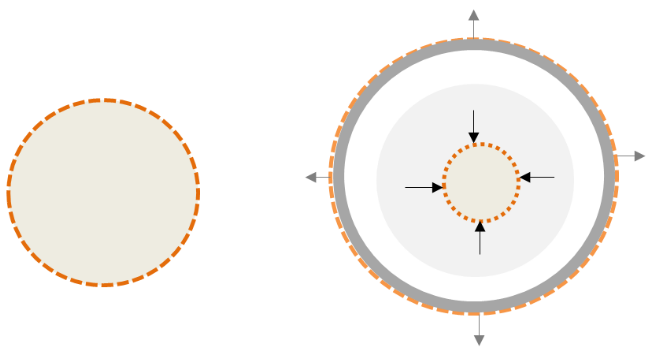


Fig.2. A positively charged object is located inside a uniformly negatively charged spherical shell. The charged object feels an expanding force from the charged spherical shell. The arrows indicate the direction of force.



a b

Fig.3. a) A negatively charged conductor ball with all the charges distributed on the surface; b) When the ball is placed inside a uniformly negatively charged spherical shell, the charges of the conductor ball are pushed towards to the center of the conductor.