Journal of Applied Mathematics and Physics, 2021, 9, 477-483
https://www.scirp.org/journal/jamp
ISSN Online: 2327-4379
ISSN Print: 2327-4352

Multiple Debye Spherical Layers and Universe

—Gravitation Originates from Electric Force

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How to cite this paper: Chi, D.L. (2021) Multiple Debye Spherical Layers and Universe. *Journal of Applied Mathematics and Physics*, **9**, 477-483.
https://doi.org/10.4236/jamp.2021.93033

Received: November 16, 2020
Accepted: March 26, 2021
Published: March 29, 2021

Abstract

Electric field superposition principle and Gauss's law are the basis of electrostatics. By extended analysis on the electric field lines of a charge, it is shown that electric field superposition principle and Gauss's law are not tenable in some states, involving the electric field of ion atmosphere that is a key concept in Debye-Hückel theory of electrolyte solution and plasma. Unveiling Debye shield, ion atmosphere (Debye spherical layer 1) actually is equivalent to continue to transmit the electric field originated from the central ion, just changing the direction of the electric field. Debye spherical layer 2 and multiple Debye spherical layers generate in the transmission. Due to the effect of the multiple Debye spherical layers of charged particles in the universe, gravitation originates from electric force.

Keywords

Electric Field Superposition Principle, Gauss's Law, Ion Atmosphere, Multiple Debye Spherical Layers

1. Introduction

Electric field superposition principle and Gauss's law are the basis of electrostatics [1] [2]. Electric field lines help us visualize the direction and magnitude of electric fields [3].

By extended analysis on the electric field lines of a charge, it is shown that electric field superposition principle and Gauss's law are not tenable in some states, involving the electric field of ion atmosphere. Ion atmosphere is a key concept in Debye-Hückel theory of electrolyte solution and plasma [4] [5] [6]. The external electric field of the ion atmosphere (Debye spherical layer 1) is equivalent to a point charge at the position of the central ion, carrying equal charge and sign opposite to the central ion. It results in the formation of multiple Debye spherical layers outside the central ion. Suppose that arbitrary objects and vacuum in the universe are made up of charged particles, due to the effect of the multiple Debye spherical layers of charged particles, gravitation originates from electric force.

2. Extended Analysis on Electric Field Lines of the Intrinsic Electric Field of a Charge

Up to now, Key ideas of electric field lines in electrostatics are the following.

A charged particle sets up an electric field (a vector quantity) in the surrounding space. Electric field lines help us visualize the direction and magnitude of electric fields. The electric field vector at any point is tangent to the field line through that point. The density of field lines in that region is proportional to the magnitude of the electric field there. Thus, closer field lines represent a stronger field. Electric field lines originate on positive charges and terminate on negative charges. So, a field line extending from a positive charge must end on a negative charge.

With the help of extended analysis on electric field lines of the intrinsic electric field of a charge, new ideas are shown in "**Figure 1**". There are some components of electric field of a charge not involving the electric field superposition in "**Figure 1(C)**". It leads Gauss' law not to hold in some states, shown in "**Figure 1(E)** and **Figure 1(F)**".

3. The State that Gauss Law does not Hold

Put the point negative charge Q_2 in "**Figure 1(C)**" become a non conductive spherical surface of radius R with uniform negative charge with same magnitude "**Figure 1(E)**"; change the positive point charge Q_1 into a non-conductive spherical surface of radius r (r < R) with uniform positive charge with same magnitude "**Figure 1(F)**". According to the basic state of the electric field lines shown in "**Figures 1(A)-(C)**", draw the electric field lines in "**Figure 1(E)** and **Figure 1(F)**".

In "**Figure 1(E)** and **Figure 1(F)**", draw an arbitrary closed surface(S) outside the spherical surface of radius R, since $Q_{\text{int}} = \sum\limits_{inside\ S} q_i = 0$, but $\oint_S \vec{E} \cdot d\vec{S} \neq 0$, hence Gauss's law doesn't hold here (Gauss's law $\phi_E = \oint_S \vec{E} \cdot d\vec{S} = \frac{Q_{\text{int}}}{\varepsilon_0}$, $Q_{\text{int}} = \sum\limits_{inside\ S} q_i$, ε_0 is permittivity of free space).

4. Unveiling Debye Shield

In Debye-Hückel theory, the central ion j of charged $-z_j e$ and a spherical ion atmosphere of charged $-z_j e$ form an electrically neutral state, and the ion atmosphere is equivalent to a spherical shell of charged $-z_j e$ "**Figure 2(A)**" [8], ion atmosphere shields the external electric field of the central ion [9] [10].

In the following, ion atmosphere is called Debye spherical layer or Debye spherical layer 1.

According to "**Figure 2(A)**", draw electric field lines of Debye spherical layer-equivalent charged shell (notice it is a non-conductive shell) and central ion "**Figure 2(B)**", show that the Debye spherical layer has an external electric field.

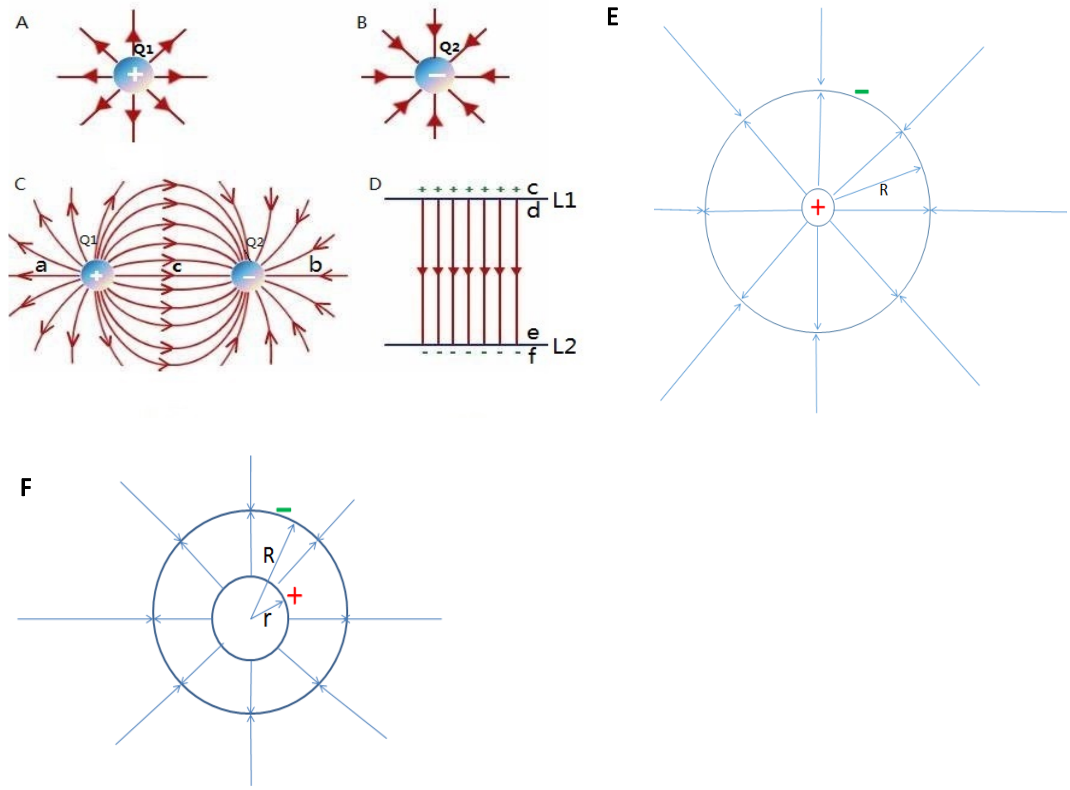

Figure 1. Electric field lines of the intrinsic electric field of a charge. (A) The field lines of a positive point charge Q_1, point away from Q_1, radial outward. (B) The field lines of a negative point charge Q_2, pointing toward Q_2, converge inward. (C) The electric field lines in the interaction of opposite point charges (Q_1, Q_2) with same magnitude. There are three electric field lines, a, b and c, remaining the states in "**Figure 1(A)** and **Figure 1(B)**". c along the segment Q_1Q_2 with two charges as the endpoints, b along the extension of the segment Q_1Q_2, a along the opposite extension of the segment Q_1Q_2. a will not terminate on Q_2, b will not origin on Q_1. It denotes E_a (one component of electric field of Q_1, represented by electric field line a) and E_b (one component of electric field of Q_2, represented by electric field line b)are not involved in the superposition of electric fields of charge Q_1 and Q_2. This reveals the superposition of the electric fields of charges (Q_1 and Q_2) only occurs in a limited range. This also shows that the principle of electric field superposition not applicable or tenable in few areas. (D) The electric field lines between L1 and L2. L1 and L2 is a pair of parallel conductive (metal) plates (or lines).The plates (lines) carry equal and opposite charges. Because opposite charges attract each other, the charges mainly concentrate on one side-d of L1 and one side - e of L2. Due to the shielding of high conductivity material (metal), the electric field of the charges in the middle of side d and e cannot radiate through the conductor (metal), there is no electric field line outside of the middle of L1 and L2. What is the state of the electric field lines of a pair of non-conductive parallel plates (lines) with opposite charge? [7] (E) The electric field lines of charges. The point negative charge Q_2 in "**Figure 1(C)**" becomes a non-conductive spherical surface of radius R with uniform negative charge with same magnitude. (F) The electric field lines of charges. The point positive charge Q_1 in "**Figure 1(E)**" becomes a non-conductive spherical surface of radius r ($r < R$) with uniform positive charge with same magnitude.

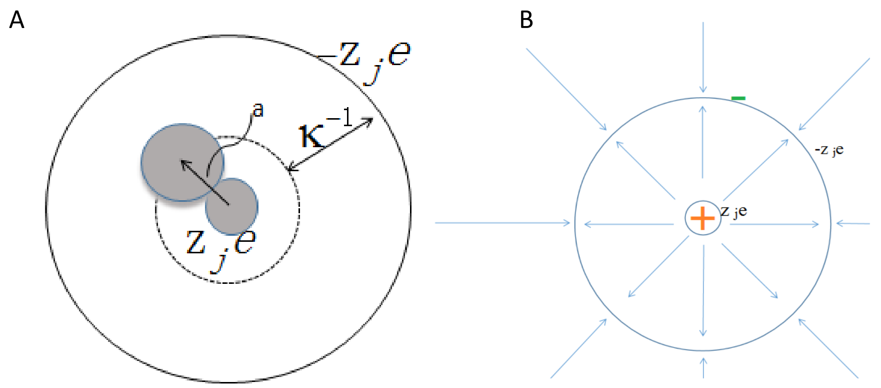

Figure 2. Electric field of ion atmosphere. (A) Mean effective ionic diameter and the thickness of ion atmosphere. The central ion j with positive charge of z_je, the negatively-charged ion atmosphere is equivalent to a spherical shell with negative charge of $-z_j$e. a is the mean effective ionic diameter, κ^{-1} is the thickness of the ion atmosphere, κ^{-1} is also known as the Debye-Hückel screening length. (B) The electric field lines of the central ion and a spherical shell with negative charge. The electric field lines in "**Figure 2(B)**" are the same as that in "**Figure 1(E)**".

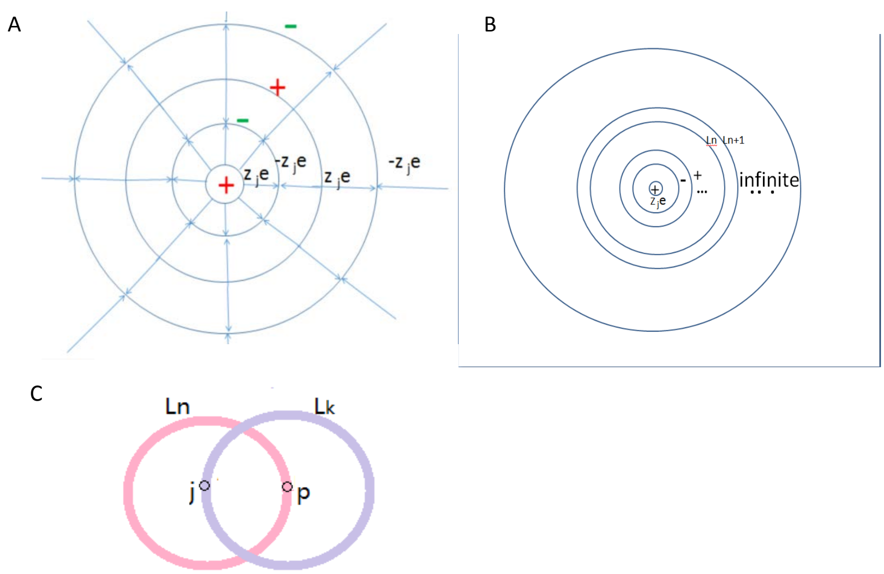

Figure 3. Multiple Debye spherical layers. (A) The electric field lines of the central ion and equivalent charged spherical shells of three Debye spherical layers. (B) The central ion and equivalent charged spherical shells of multiple Debye spherical layers. (C) An arbitrary ion p is in Debye spherical layer n due to the central ion, the central ion is also in Debye spherical layer k due to ion p.

Debye spherical layer (Debye spherical layer 1) is equivalent to a point negative charge with same magnitude as the center ion at the position of the center ion. The external electric field of Debye spherical layer 1 causes Debye spherical layer 2 to generate, Debye spherical layer 2 is equivalent to a point positive charge with same magnitude as the center ion at the position of the center ion; the external electric field of Debye spherical layer 2 causes Debye spherical layer 3 to generate "**Figure 3(A)**" …

The external electric field of Debye spherical layer n causes Debye spherical layer $n + 1$ to generate, $R_{n+1} > R_n$ (n is a natural number, R_n is the radius of Debye spherical layer n), Multiple Debye spherical layers generate "**Figure 3(B)**". There may be infinite Debye spherical layers outside the central ion, as long as the space of electrolyte solution or plasma is large enough.

The field lines can show, if ignore changes of electric field direction, the electric field originated from the central ion in the multiple Debye spherical layers is equal to the electric field due to the central ion alone, comparing with "**Figure 1(A)**".

Every ion plays the role of the central ion of multiple Debye spherical layers, also plays the role of the member of multiple Debye spherical layers of other ions. Ion p is in L_n (Debye spherical layer n due to the central ion j), the central ion j is also in L_k (Debye spherical layer k due to ion p) "**Figure 3(C)**".

5. Discussion and Summary

1) The ion atmosphere, *i.e.* Debye spherical layer, *i.e.* Debye spherical layer 1, does not shield the electric field of the central ion, just cunningly reversing the direction of the electric field, continuing to transit the electric field originated from the central ion, and causing multiple Debye spherical layers to generate.

2) The absolute value of the electric field originated from the central ion in the multiple Debye spherical layers is equal to the absolute value of electric field due to the central ion alone $|E| = \frac{|Q_j|}{4\pi R^2}$, here $|Q_j|$ is the absolute value of the magnitude of charge of the central ion, R is a distance from the central ion j.

3) Debye spherical layer n + 1 and Debye spherical layer n carry equal and opposite charges. They are of same magnitude as the central ion j.

4) Since Debye spherical layer 1 and the central ion j carry equal and opposite charges, there is an electric attraction between the central ion j and Debye spherical layer 1. In the same way, there is also electric attraction between arbitrary two adjacent layers (layer n, layer $n + 1$) in multiple Debye spherical layers, Then the central ion j can attract any Debye spherical layer due to the central ion j. The attraction intensity of the central ion j to any layer is proportional to $\frac{|Q_j|}{4\pi R^2}$.

5) Due to the attraction of the central ion j to any Debye spherical layer, for an arbitrary ion p in one Debye spherical layer, ion p as one member of the layer, there must be an indirect attraction of the central ion j to ion p, no matter the charge sign of ion p. The indirect attraction intensity of the central ion j to ion p is proportional to the attraction intensity of the central ion j to the layer. Since the distance between the central ion j and the layer that involves ion p is approximate to the distance between j and p, the indirect attraction intensity $F_{j \leftarrow p}$ of the central ion j to ion p is approximately proportional to $\frac{|Q_j|}{4\pi R^2}$, here R is a

distance between j and p, *i.e.* $F_{j\leftarrow p}=\frac{|Q_j|}{4\pi R^2}$.

6) Ion p is in L_n (Debye spherical layer n due to the central ion j), the central ion j is also in L_k (Debye spherical layer k due to ion p). The indirect attraction intensity $F_{p\leftarrow j}$ of ion p to the central ion j is approximately proportional to $\frac{|Q_p|}{4\pi R^2}$, here Q_p is the magnitude of charge of ion p, R is a distance between j and p, *i.e.* $F_{p\leftarrow j}=\frac{|Q_p|}{4\pi R^2}$.

7) Due to 5 and 6, the total indirect attraction intensity $F_{indirect}=F_{\substack{j\leftarrow p\\ p\leftarrow j}}$ between ion j and p, is approximately proportional to $\frac{|Q_j|}{4\pi R^2}$ and $\frac{|Q_p|}{4\pi R^2}$, $F_{indirect}$ is approximately proportional to $\frac{|Q_i||Q_p|}{4\pi R^2}$. Reduce the precision, $F_{indirect}$ is right proportional to $\frac{|Q_i||Q_p|}{4\pi R^2}$, *i.e.* $F_{indirect}=F_{\substack{j\leftarrow p\\ p\leftarrow j}}=H\frac{|Q_i||Q_p|}{R^2}$, H is a proportional constant. Comparing the indirect attraction intensity $F_{indirect}=H\frac{|Q_i||Q_p|}{R^2}$ with Coulomb's force $F_C=k\frac{|Q_i||Q_p|}{R^2}$, $k=8.99\times10^9\,\mathrm{N\cdot m^2/C^2}$ [11], in Coulomb's force, when the charges are the same sign, the force is repulsive, when the charges are opposite signs, the force is attractive; in the indirect attraction intensity $F_{indirect}=H\frac{|Q_i||Q_p|}{R^2}$, no matter the charges are the same sign or opposite signs, the force is always attractive.

8) Suppose that an arbitrary object and vacuum in the universe are all made up of charged particles, comparing a volume charge density defined by $\rho_e=\lim_{\Delta V\to0}\frac{\sum_{inside\ \Delta V}Q_i}{\Delta V}$, a volume density of charge absolute is defined by $\rho_{|e|}=\lim_{\Delta V\to0}\frac{\sum_{inside\ \Delta V}|Q_i|}{\Delta V}$, $\rho_{|e|}$ of vacuum is the smaller than that of an arbitrary object, but $\rho_{|e|}\neq0$ everywhere.

Due to the effect of multiple Debye spherical layers of charged particles in the universe, for two arbitrary objects A and B, there is an indirect attraction between A and B, and its intensity $F_{indirect}=H\frac{\sum_{inside\ V_A}|Q_i|\sum_{inside\ V_B}|Q_j|}{R^2}$, $\sum_{inside\ V_A}|Q_i|$ is the sum of the absolute value of charge magnitude of each charged particle in the space occupied by the object A, $\sum_{inside\ V_A}|Q_j|$ is the sum of the absolute value of charge magnitude of each charged particle in the space occupied by the object B.

Comparing the indirect attraction intensity $F_{indirect} = H \frac{\sum_{inside\ V_A} |Q_i| \sum_{inside\ V_B} |Q_j|}{R^2}$ with Newton's universal gravitation $F = G\frac{m_A m_B}{R^2}$, G is gravitational constant, $G = 6.674\times10^{-11}\,\mathrm{N}\cdot\mathrm{m}^2/\mathrm{kg}^2$, m_A, m_B is the mass of A and B respectively, then $m_A = \sum_{inside\ V_A} |Q_i|$, $m_B = \sum_{inside\ V_B} |Q_j|$, $H = G$ or $H = \varphi G$, φ is a constant.

Acknowledgements

Special thanks to Professor Biping Gong, Professor Xiaotian Li, Professor Hefa Lv, My Assistant Jingsen Wu and all who supported me. Last but not least, I would like to give special thanks to Michael Faraday who invented the electric field line.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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