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Research on the Application of MAPLE Software in the Visualization of Physical Quantities of Point Charge System

Hongfang Gong, Zhijun Ma*

College of Physics and Electronic Science, Hunan University of Science and Technology, Xiangtan 411201, Hunan, China.

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***Corresponding author:** Zhijun Ma, College of Physics and Electronic Science, Hunan University of Science and Technology, Xiangtan 411201, Hunan, China.

Abstract

For the physical quantities of the charged system including electric field strength and potential are more difficult to visualize, this paper takes the point charge system as an example, the system tends to be complicated by the superposition of fields due to the increase in the number of point charges and the inhomogeneity of the distribution, and it is more and more difficult to construct the physical image of the system. Starting from the Poisson equation of the point charge system, the distribution of electric potential in space can be obtained, and by the relationship of the electric field is equal to the negative gradient of the electric potential, and then the electric field strength of the system. MAPLE-based computer simulation is introduced into the teaching of electromagnetism, which helps to visualize the complex and abstract physical formulas in an intuitive and graphic way, and stimulate students' interest in learning as well as enhance their knowledge and understanding of physical laws.

Keywords

MAPLE; Electrostatic field; Point charge; Visualization

Electromagnetism is an important branch of university physics. Electric field and magnetic field are its main contents. Field is an objective substance, but it is invisible and intangible, which brings great difficulties to the intuitive and vivid teaching of electrostatic field.

MAPLE is one of the three major mathematical software [1]. It is very powerful and has excellent symbolic computing capabilities, numerical computing capabilities, visualization functions, etc. The mathematical formula display interface is user-friendly and can be used for simple programming [2]. It can convert some abstract physical Concepts are presented graphically, making it easier for students to understand and apply physical laws.

In this paper, we take the electric field generated by a point charge system as an example. Starting from the Poisson equation [3], we derive the electric potential and electric field of the point charge system through the superposition principle of electric fields. At the same time, we use MAPLE to draw the corresponding physical graphs to visually understand the spatial distribution of the electric field and potential.

1. Point charge system

The electric potential of φ the point charge system satisfies the Poisson equation, which can be expressed in the CGS system as:

$$\Delta\varphi = \sum_i 4\pi\delta(r - r_i)Q_i$$

Note: The article was originally published in *Physical Science and Technical Research*, and this is an authorized translation of it.

where Q_i is the charge at location r_i.

The solution of this differential equation, that is, the electric potential of the point charge system:

$$\varphi = \sum_i \frac{Q_i}{r - r_i}$$

In a three-dimensional rectangular coordinate system, the electric potential expression of a point charge is:

$$\varphi = \sum_i \frac{Q_i}{\sqrt{(x - x_i)^2 + (y - y_i)^2 + (z - z_i)^2}}$$

Thus, the expression of electric field strength is obtained:

$$E = \sum_i Q_i \frac{(x - x_i)e_x + (y - y_i)e_y + (z - z_i)e_z}{[(x - x_i)^2 + (y - y_i)^2 + (z - z_i)^2]^{\frac{3}{2}}}$$

where e_x, e_y, e_z is the unit vector of the three-dimensional rectangular coordinate system.

2. Equal amount of the same charge

First, let us consider the simplest case, a system composed of two equal charges of the same kind, with the two charges x symmetrically distributed on the axis. The electric field strength generated by this system is shown in Figure 1. In addition to the peaks at the positions of the two-point charges, there is also an inverted peak at the origin of the coordinate system, and the field strength corresponding to the peak is exactly zero. At the same time, we can intuitively see that the electric field generated by the two same charges has no point with zero field strength except at infinity. In addition, in the perpendicular plane between the two charges, when changing along y the axis, the electric field strength has two maxima [4]. This is the conclusion drawn from the graph.

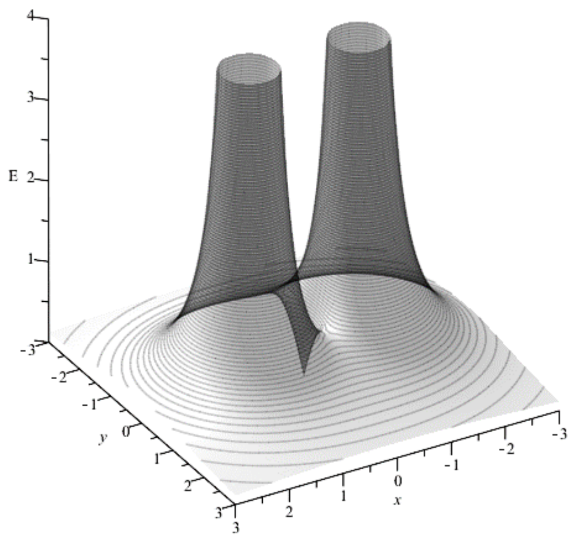

Figure 1. The magnitude of the electric field strength induced by equal charges of the same kind.

Figure 2 shows the distribution of the electric potential of the system in space. A xOy tangent line parallel to the plane can be seen between the two peaks (i.e., the midpoint of the two charge positions). The tangent point is at x the axis and y the axis origin. The spatial rate of change, i.e., the electric potential gradient, is zero, and the corresponding electric field strength is zero. Except for this point and the space far away from the source point, the electric potential gradient is not zero, and the field strength is always non-zero. We have reached this conclusion again, which also reflects the relationship between the electric field strength and the electric potential gradient.

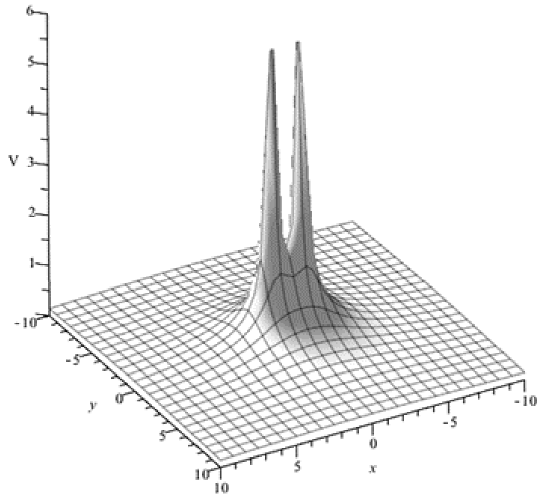

Figure 2. The potential induced by equal charges of the same kind.

3. Multi-charge systems

consisting of three-point charges: two positive and negative charges x are symmetrically distributed on the axis, and there is a positive charge located on y the axis. At this time, the charge distribution of the system is no longer symmetrical, the physical diagram becomes slightly more complicated, and the distribution of the electric field potential is not as easy to imagine as the above two equal and identical charge systems.

In order to describe the electric field vividly, and considering that the electric field is a vector field, we E draw the direction of the electric field lines (the integral curve of the electric field [6]) in Figure 3 in the form of arrows [5]. At the same time, note that the direction of the electric field is the direction in which the electric potential drops fastest, that is, the equipotential lines are perpendicular to the electric field lines. Based on this, we also draw the equipotential lines in Figure 3. It is easy to see from the graph that the line density around the negative charge is significantly larger. Since the density of the electric field lines and equipotential lines is proportional to the magnitude of the electric field strength, it can be seen that the field strength near the negative charge is higher than that at other locations. We can also observe that between any two charges, the density of equipotential lines changes from dense to sparse, and then from sparse to dense, indicating that there is an extreme point of the electric field between the two charges. The above are some of the characteristics of this system that we have obtained from the electric field lines and equipotential line graphs.

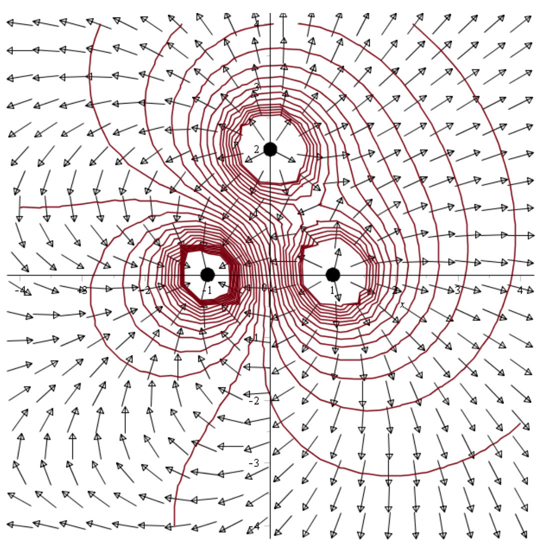

Figure 3. Electric field lines and equipotential lines in a multi-charge system.

Figure 4 shows the three-dimensional spatial distribution of the system's electric potential. From the figure, we can see that the distribution of the electric potential shows an asymmetric behavior, and y the electric potential peak corresponding to the positive charge on the axis increases significantly faster. The reason is that the charge is farther away from the negative charge and closer to the positive charge. The scalarity of the electric potential makes it easy to express its inversely proportional characteristics with the distance from the field point. On the other hand, in physical phenomena, the field strength around the negative charge is larger, so the electric potential changes faster. At the same time, we can easily see that if we do not consider the infinite distance, the point where the electric field is zero is and only is between the two positive charge peaks. This is a conclusion that is difficult to imagine but very intuitive in the graph.

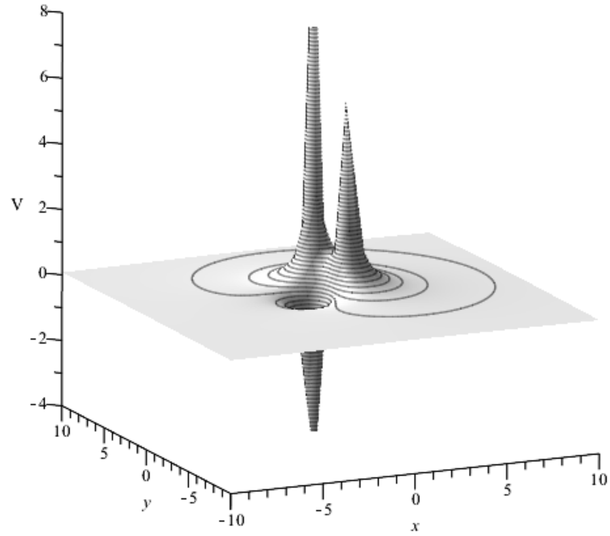

Figure 4. Potential of excitation in multiply charged systems.

Finally, Figure 5 shows the distribution of the electric field strength of this system. It is not difficult to see that the graph of the electric field strength has a zero point and three extreme points between peaks. Based on the characteristics of the graph, we can draw a physical conclusion that is self-consistent and consistent with the above. At the same time, it also shows once again that the electric field and electric potential are closely related.

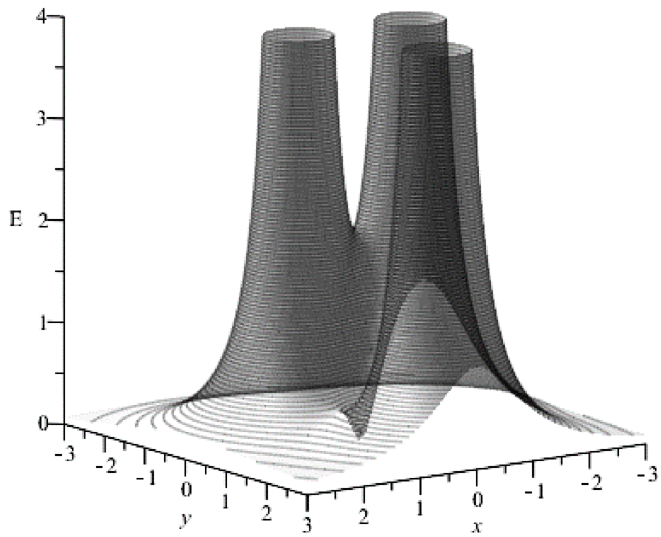

Figure 5. The magnitude of the electric field strength excited by a multi-charge system.

4. Conclusion

The above discussion discusses the electric field potential distribution and physical meaning of the point charge system under two situations. The Poisson equation can be extended to other point charge systems or a class of continuous charged bodies. This article takes the knowledge point of the electric field excited by the point charge system in college physics and electromagnetism as an example. Through MAPLE program design, the originally abstract and difficult physical concepts and knowledge points are visualized, which is highly convenient for students to understand. Visual programming based on MAPLE program design and its application in teaching can not only improve teaching effectiveness, but also stimulate students' interest and improve learning efficiency. It is a very recommended teaching method.

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