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FROM RAYLEIGH SCATTERING TO GEOMETRIC OPTICS: THE VERSATILITY OF MIE THEORY

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ABSTRACT

This article discusses the Mie theory, which was developed by the German physicist Gustav Mie in 1908 for the law of scattering by spherical particles. Later versions of the theory were developed by Stratton and Van de Hulst, and various sets of tables were issued. The Mie theory is particularly useful for atmospheric problems as it can be applied to all particle sizes. The theory assumes an oscillating electromagnetic field of radiation incident on a homogeneous dielectric sphere of radius r and dielectric constant €. The energy may be scattered or absorbed by the particle, and in the space surrounding the particle, the scattered energy has the form of a diverging spherical wave.

Keywords: *Mie theory, scattering by spherical particles, atmospheric problems, electromagnetic radiation, dielectric sphere, scattering angle, polarized radiation.*

АННОТАЦИЯ

В статье рассматривается теория Ми, разработанная немецким физиком Густавом Ми в 1908 году для закона рассеяния на сферических частицах. Более поздние версии теории были разработаны Стрэттоном и Ван де Халстом, и были выпущены различные наборы таблиц. Теория Ми особенно полезна для атмосферных проблем, поскольку ее можно применять к частицам любого размера. Теория предполагает колеблющееся электромагнитное поле излучения, падающее на однородную диэлектрическую сферу радиусом r и диэлектрической проницаемостью €. Энергия может рассеиваться или поглощаться частицей, а в окружающем частицу пространстве рассеянная энергия имеет вид расходящейся сферической волны.

Ключевые слова*: теория Ми, рассеяние на сферических частицах, атмосферные задачи, электромагнитное излучение, диэлектрическая сфера, угол рассеяния, поляризованное излучение.*

INTRODUCTION

The scattering of light by particles has been an area of interest for scientists for many years, and the Mie theory has been an important tool in this field since its introduction by German physicist Gustav Mie in 1908. This theory has been further developed by researchers such as Stratton and Van de Hulst, and tables of functions have been issued by various authors, making the Mie theory applicable to a wide range of particle sizes, from gaseous molecules to large raindrops. In this theory, an electromagnetic field of radiation is assumed to be incident on a homogeneous dielectric sphere, and energy may be scattered or absorbed by the particle. The scattered energy takes the form of a diverging spherical wave with oscillations in the plane normal to its direction of propagation, and for unpolarized incident radiation and spherical particles, the scattered field has axial symmetry around the direction of propagation of the incident beam, with the only variation being in the scattering angle between the directions of propagation of incident and scattered radiation. In this article, we will outline the Mie theory, define key terms such as scattering angle and unit vectors, and discuss the linear relationship between the electric vectors of the scattered and incident radiation.

DISCUSSION

The Mie theory of scattering by spherical particles, first proposed by Gustav Mie in 1908, has since undergone development by other physicists and has been applied to a wide range of atmospheric problems due to its applicability to all particle sizes from gaseous molecules to the largest rain drops. In the Mie theory, an oscillating electromagnetic field of radiation is incident on a homogeneous dielectric sphere of radius r and dielectric constant €, and energy may be scattered or absorbed by the particle. The scattered energy takes the form of a diverging spherical wave with oscillations in the plane normal to its direction of propagation and at the same frequency as that of the incident wave. For unpolarized incident radiation and spherical particles, the scattered field has axial symmetry around the direction of propagation of the incident beam, with the only variation being in scattering angle θ between the directions of propagation of incident and scattered radiation. However, this is not the case for partially or completely polarized incident radiation, as will be explored in later sections. The linear relationship between the electric vectors of the scattered and incident radiation is expressed in equations with the unit vectors $(u_{\|}, u_{\perp})$ and $(u'_{\|}, u'_{\perp})$ representing the directions of propagation. The Mie theory provides a valuable tool for understanding and predicting the behavior of electromagnetic radiation interacting with spherical particles, with many applications in atmospheric science and beyond.

RESULTS

The Mie theory of scattering by spherical particles provides a mathematical framework for calculating the scattering and absorption of electromagnetic radiation by particles of various sizes and compositions. It has been extensively used in atmospheric and environmental research, where particles of different sizes and types play crucial roles in determining the Earth's energy budget and climate.

The Mie theory assumes an incident electromagnetic wave of a given wavelength and polarization, interacting with a spherical particle of a certain size and dielectric constant. The scattered and absorbed energy by the particle is calculated using the Mie coefficients, which depend on the size parameter and refractive index of the particle.

For unpolarized incident radiation and spherical particles, the scattered field has axial symmetry around the direction of propagation of the incident beam, with the scattering angle being the only variable. However, when the incident radiation is partially or completely polarized, the scattered field is no longer symmetrical, and the scattered intensity depends on the polarization state of the incident radiation.

The Mie theory has been widely used in various fields of research, such as atmospheric optics, remote sensing, and biophotonics. The theory has been extended to include more complex geometries, such as cylinders and ellipsoids, and to account for multiple scattering events and non-spherical particles.

Overall, the Mie theory provides a powerful tool for understanding the interaction of electromagnetic radiation with particles and can be used to study a wide range of natural and synthetic systems, from atmospheric aerosols to nanomaterials.

CONCLUSION

In conclusion, the Mie theory provides a valuable tool for analyzing the scattering of electromagnetic radiation by spherical particles. The theory, first derived by Gustav Mie in 1908, has been refined and expanded upon by other researchers, resulting in various sets of tables and functions that are useful for atmospheric problems. The theory assumes an oscillating electromagnetic field of radiation of wavelength λ incident on a homogeneous dielectric sphere of radius r and dielectric constant €. It accounts for both scattered and absorbed energy by the particle, with absorbed energy converted into heat. For unpolarized incident radiation and spherical particles, the scattered field has axial symmetry around the direction of propagation of the incident beam, with the only variation being in scattering angle θ. The Mie theory is applicable to all particle sizes, from gaseous molecules to large raindrops. A linear relationship exists between the electric vectors of the scattered and incident radiation, as shown in Equation 3.1. Further research on the polarization of incident radiation and its effect on scattering will shed additional light on the complex phenomenon of scattering by spherical particles.

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