Methods for calculating light scattering by single particles

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Part I. Exact methods

The general formulation of the problem of light scattering (diffraction) is rather simple. The field $\vec{E}_0$ is incident on a scatterer of the volume V, and creates the field $\vec{E}_{\rm i}$ inside the scatterer and an additional (diffraction) field $\vec{E}_{\rm s}$ outside it. Thus, from Maxwell's equations one should find the total field $\vec{E}$ equal to $\vec{E}_{\rm i}$ inside V and to $\vec{E}_0 + \vec{E}_{\rm s}$ outside V and satisfying the boundary conditions on V. Despite the simplicity of the scheme, a concrete solution of the problem essentially depends on the geometry of the scatterer and its structure. For instance, even for spherical scatterer with an anisotropic tensor of the refractive index, a general solution cannot be obtained in a closed form [7]. Therefore, in the theory of light scattering by small particles one has developed various methods whose applicability regions and efficiency depend on the concrete conditions. In this part we discuss the exact methods which include both the analytical and numerical approaches, since from a contemporary point of view an efficient numerical algorithm realized at a computer is equivalent to an analytical solution which as a rule also needs non-trivial calculations.

1 Separation of variables method

1.1 Spherical particles

The classic solution for homogeneous sphere was suggested in 1899 by A.E.N. Love [330], in 1908 by G. Mie [342] and in 1909 by P. Debye [199]. In 1910 Lord Rayleigh [422] obviously knowing nothing about the works of Mie and Debye removed a mistake in the paper of Love. Traditionally the theory of light scattering by a sphere is called the Mie theory. The solution for a focused Gaussian beam (called the generalized Mie solution) was first derived in the work [230] (see [236]) and developed further in [236, 333]. The same problem was recently considered in [61] and its detailed analysis see in [329]. With the appearance of powerful PCs the computation using the Mie theory practically became a routine. Nevertheless, even in 1994 we find a paper [19] published on the Mie theory where a closed integral representation of the extinction cross-section was obtained (in other words the Mie series was transformed into an integral). To some extent unusual results for magnetic spheres were presented in [279].

The generalization of the Mie theory for core-mantle spheres was made in 1951–2 by A.L. Aden and M. Kerker [133] and K.S. Shifrin [125] and for the case of an arbitrary number of layers in [343, 490]. Detailed results for layered spheres can be found in [274, 276, 277]. A core-mantle sphere as the model of biological particles was first considered in [168, 169, 198], a detailed study of this and three-layered model of cells was done in [46, 49, 50]. For an inhomogeneous sphere with an arbitrary radial distribution of the refractive index, the general formal solution was obtained in [504, 505] (see also [325, 435]), and in [501] all refractive index profiles for which the radial solutions are expressed via the known functions were given. A thorough investigation of the problem of light scattering by inhomogeneous spheres was done by the group of A.P. Prishivalko [71, 72] (nearly all literature on this question is cited in the monograph [72]) and in the recent paper of A.Ya. Perelman [67].

The exact solutions of the Mie problem for an optically active sphere (i.e. a sphere of optically active material [7]) and for a sphere with an optically active mantle were first obtained in 1974–5 by S. Bohren [158, 159]. As it was mentioned, for a sphere of anisotropic material, the solution of the general type like the Mie theory does not exist. Nevertheless for spheres with the axial anisothropy of material a successful attempt to separate variables was undertaken in 1989 by J.S. Monzon [371] who not only got the expansions of the fields, but also obtained numerical results. The approximate methods of treatment of anisotrophic particles are considered below.

V.I. Rosenberg [76] generalized the Mie solution for the case of an arbitrary number of spherical particles by using the theorems of summation of the spherical harmonics [196]. Last years the problem of light scattering by clusters of spherical particles is very extensively studied (see the papers [21, 99, 107, 110, 111, 114, 195, 219, 220, 221, 222, 280, 286, 317, 354, 355, 362] and references therein), but the work [76] remains apparently unknown to western scientists.

1.2 Cylinders

For an infinitely long circular cylinder, the solution of the light scattering problem for the perpendicular incidence was first derived by Rayleigh [418] who returned to this problem once again in his last work [417] written a short time before his death. The problem for oblique incidence was solved in 1955 by J.R. Wait [491] (Kerker [274] at p.256 mentions also the paper of Blank, 1955); a bit later the same result was obtained in [172]). A detailed investigation of light scattering by a cylinder was made in works [41, 42, 131, 153, 154, 189, 190, 233, 234, 326, 327, 430, 438] (homogeneous particles), [134, 215, 270, 274, 278] (multi-layered cylinders). Though in principle the separation of variables is possible also for non-circular cylinders (see, e.g., the paper of Rayleigh [419]), numerical methods in this case are more efficient (see below and the papers [380, 424]). For an anisotropic cylinder with the coaxial symmetry of the refractive index tensor, no principal differences appear [7, 31, 34, 72]. The exact solution for a thin bianisotropic cylinder was given in [311], for an optically active cylinder in [160], and for magnetized cylindrical plasma in [400].

1.3 Spheroids

In the scalar Helmholtz equation the variables are separated in 11 physically interesting coordinate systems [55], however for the vector field containing 3 scalar functions, the complete separation of variables is possible only in 6 systems: Cartesian, 3 cylindrical, conical and spherical ones ([55], Ch.13). Therefore, the formal solution suggested in 1927 by F. Moeglich [368] for the spheroidal coordinates was practically usefulness until the work of Sh. Asano and G. Yamamoto in 1975 [141] where the method of separation of variables was adapted for numerical calculations by cutting the infinite linked (only partly separated) systems of equations (in earlier papers [432, 433] one considers either scalar scattering, or the axial incidence of the electromagnetic wave). In 1980–1983 V.G. Farafonov [87, 88, 93] improved the method of Asano–Yamamoto by use of an original scheme of separation of the fields in two types with the invariant angular parts [27]. At the moment the use of both approaches gave large volume of data on the light scattering by spheroidal particles [13, 14, 15, 16, 17, 89, 90, 91, 92, 138, 139, 140, 141, 297, 323, 413, 430].

2 Point matching method

In this method the fields outside and inside a particle are represented by expansions in term of proper basis functions (practically always the vector spherical harmonics). Since the particle surface does not coincide with the coordinate surface, it is impossible to satisfy the boundary conditions exactly, and the expansions are limited by a finite number of terms, and the boundary conditions are considered in a finite set of points (matching points). From the derived system of equations one finds the expansion coefficients. The first results for scalar scattering by a spheroid were obtained in [234], but a generalization for the electromagnetic case appeared only in 1973–1974 [373, 374, 382, 385]. A review of evolution and applications of this method can be found in [100, 148]. A similar version of the projected(?) Galerkin method was developed in [8] (the corresponding papers are also mentioned in [100]). Now the point matching method is nearly totally displaced by more efficient algorithms.

3 Integral equation method

This method occupies a particular place among the methods of solution of diffraction problems. It is a general approach where using the Green functions the boundary-value problem is transformed into the integral form including the boundary conditions and the radiation conditions at infinity [83, 401, 506]. Therefore, this method is not only a numerical approach, but in fact a basis for formulation of other methods (e.g., the method of moments [243, 495], the T-matrix method [147, 463], Rayleigh-Debye-Gans theory [25, 441]).

Pioneer rigid calculations using this method were performed in 1964–1965 [136, 137, 424]. A detailed discussion of the questions connected with the application of the integral equations to light scattering problems can be found in [24, 401, 464]. For solution of the integral equations one uses different methods: method of moments, Galerkin method, etc. [228, 243, 265, 380, 434, 467, 495, 500]. From the integral equations one can calculate scattering and absorption by particles of different shape and structure: cubes [272], disks [301, 500], cylinders of any shape (cross-section) [380, 424, 434], finite thin rods [476], any structure aggregates of spherical particles [175, 265] and so on.

In 1972–1973 in a series of two papers A.R. Holt and V. Santoso [258] formulated the quantum mechanics problem of scattering by a central potential (Schroedinger equation) in the form of the Fredholm equation of the 2nd kind. It was shown that the algorithm is stable, since it automatically satisfies the variational principle. In the subsequent papers applications to the problems of light scattering by cylinders [257, 476, 478] and spheroids [260, 477, 478] were developed. In 1990 this method was formulated in general case for anisotropic spheroids [387], but numerical results were presented only for anisotropic single axis sphere.

4 Coupled dipoles method (Purcell–Pennypacker, CDM)

In the theory of light scattering by small particles this method became extensively applicable after the paper of E.M. Purcell and C.R. Pennypacker in 1973 [404], though without doubt the physical basis of the method was known and applied in other fields earlier (see, for instance, the review of A. Lakhtakia in 1992 [307] who cites the work of Gray published in 1916 and others). In the western literature this method is now called "coupled dipole method" (CDM). The physical formulation of the method is rather simple. A particle is divided into a set of small domains so that each of them can be considered as a dipole scatterer. Each of the domains is exited by the field of the incident wave and by the the fields scattered by all other domains. Thus, a system of equations relative to the fields scattered by the elementary domains can be obtained, and summation of these fields gives the total scattering field. The accuracy of the method depends on the number, size and shape of the elementary domains as well as on some features of selected expression for their polarizability [209, 307, 313, 317].

Initially the CDM was applied to spherical elementary domains with the usual polarizability of a dipole sphere, but later two modifications were suggested: 1) radiation damping was included into the expression for the polarizability of a small sphere (in order to fulfill the optical theorem) [209]; and 2) the polarizability of the sphere was computed on the basis of the first term of the Mie expansion [210]. Since both modifications were made from physical reasons, the problem of confrontation of different modifications of the CDM and of the method of moments arisen. The problem was successfully solved by Lakhtakia [307, 313, 317]. First, he compared the CDM and solution of the volume integral equation by the method of moments, where the scatterer is also divided into domains. A subtle difference between both methods is in the fact that in the first method one works with the fields which excite a dipole (without the field of the dipole), whereas in the second method one uses the real fields in a given domain. In the rigid formulation both methods became equivalent (i.e. the systems of the algebraic equations could be obtained one from another). Further, Lakhtakia considered the problem of obtaining the dyadic polarizability for a small anisotropic region of an arbitrary shape and showed its two forms: "strong" one including contribution of self-interaction or radiation damping (they are analogous but not equivalent [209]), and "weak" one coinciding with the Purcell–Pennypacker formulation. If one uses the equivalent forms (strong or weak) of the CDM and the moment of moments, there is no principal difference between them. The important result of this analysis was the development of a general approach to calculation of the polarizability from rigid integral equations which was later applied to bianisotropic [308, 313] and chiral [309] small particles as well as formulation of the generalized CDM for such scatterers [307, 310, 315, 317]. Note that independently of this work a generalization of the CDM for optically active and chiral particles was made in [449, 450, 454], and use of the anisotropic elementary dipoles was discussed in [455]. Lakhtakia used the derived general equations for dyadic polarizability to generalize the classic theory of Maxwell Garnett for the effective optical constants of composite media [305, 306, 308, 309, 310, 312, 315, 436]. Note that in works of A.G. Ramm [74, 405] a general formalism of calculations of the polarizability was also developed for the body of an arbitrary shape, but the formalism did not include the radiation damping and was applied only to generalize the Rayleigh scattering theory.

Solution of the equation systems in the CDM demands essential computer resources (memory and speed of CPU). In 1978 Y.L. Yung [510] attempted to use the variational principle for energy to increase the efficiency of the CDM and to bring the calculations to iterations, but his results did not find a further use. In 1987–8 Sh. Singham and C.F. Bohren [452, 453] reformulated the equations of the CDM as a sequence of multiple interdipole scatterings, which significantly increased the efficiency of the algorithm. It should be noted that the priority in formulation of this idea belongs to R. Chiappetta's work of 1980 [181]. The approach was used in [182, 183] to analyse scattering by spheroids and spiral structures.

The paper [451] suggested a hybrid scheme where the particle was divided into domains larger than usually in the CDM and within which the fields were calculated exactly (or approximately), and then the iteration scheme of the CDM was applied or a lower order system of linear equations was solved. Generally, the same idea in a slightly modified form was realized in [165]. One of the advantages of the CDM is that the equations have a certain symmetry and allow one to use the powerful apparatus of the quantum theory of angular momentum for orientation averaging for ensembles of chaotical oriented [336, 440, 448] and aligned [466] particles. Though these works were done for macromolecular solutions (see also the application of an analogous approach in [157]), we believe that their ideas have a much wider application including the light scattering theory. For instance, in the following section one will see that the apparatus of the quantum mechanics theory of angular momentum is a powerful tool in the T-matrix method.

The analysis of the cited literature (see also [21, 171, 174, 302, 304]) allows one to conclude that in coming years the CDM will be one of the most popular methods in the theory of light scattering by particles of complex shape and structure. As an illustration of its large possibilities we refer to the paper [484] where the rigid quantitative results were obtained for scattering by an anisotropic sphere.

5 T-matrix method (EBCM)

The T-matrix or transition matrix is well known in the quantum theory of scattering [56] where one also uses the Heisenberg S-matrix connected with the T-matrix by the relation $\hat{S} = 1+2\hat{T}$. In contrast to the coordinate representation in the integral equation method, where the scattered and incident fields are connected by the Green function, the T-matrix connects the coefficients of the expansions of the scattered and incident fields in terms of a complete system of the vector basis functions. In the theory of light scattering the T-matrix first appeared in the pioneer works of P.C. Waterman in 1965–1979 [496, 497, 498, 499]. The initial formulation used the Huygens principle for perfectly conducting [496] and dielectric [498] particles was generalized in [497] where also different ways of formulation of the method equations without the Huygens principle and fictive sources were considered. Although the papers of Waterman [496, 497, 498, 499] contained exhaustive information on principal and technical features of the method, it attracted the attention of scientists in the optics only after the publication of the paper of P.W. Barber and C. Yeh in the Applied Optics in 1975 [147] where the method was formulated using the Shelkunov equivalence theorems and called the Extended Boundary Condition Method – EBCM. Now both names are nearly equally used. The further works of Barber's group [142, 143, 144, 145, 146, 227, 324, 328, 493, 494, 508] also had a noticeable influence on the growth of the method popularity. The generalization of the T-matrix method for multi-particle configurations were developed in [300, 395, 464], for multi-layered scatterers in [300, 396, 493], and chiral particles of non-spherical shape in [314, 319]. For strongly aspherical weakly absorbing particles, the convergence of the T-matrix method is rather weak, therefore an iterative modification of the algorithm was suggested in [267] with further development and applications in [266, 268, 269, 316, 318]. From the computational point of view, the method convergence problems for strongly aspherical particles of large size are connected with the errors of calculations of the integrals defining the T-matrix [49, 60], therefore a simple and effective way of solution of this problem is the transition to representation of numbers in the computer with extended accuracy [359, 361].

The analysis of the scattering characteristics of polydisperse ensembles of particles with random orientation needs two additional integrations – over size and orientation of scatterers and hence larger computational resources. Therefore, very important is the derivation of equations for the analytic orientational averaging of all physically interesting optical characteristics: the integral cross-sections and Mueller matrix [54, 98, 281, 345, 350, 348], the extinction matrix of the transfer equation [344, 348] and small-angle scattering flux [57, 388]. Using the apparatus of the quantum theory of angular momentum we demonstrated that the equations for the orientational averaging of the T-matrix and its bilinear forms (and hence the physically observer quantities) do not depend on the particle nature and scattering waves [98, 281]. In the works of M.I. Mishchenko [344] and L.E. Paramonov [59, 60] (see also the references in [60]) this approach was generalized for disperse systems with ordered orientation of particles. The numerical algorithms built on the equations of the analytical orientational averaging were found to be the most efficient ones for the analysis of light scattering characteristics of ensembles of non-spherical particles with random orientation (see the works of Mishchenko's group at the NASA Goddard Institute for Space Studies [345, 346, 347, 348, 349, 350, 351, 352, 353, 354, 355, 356, 357, 358, 359, 360, 361, 362] and also the papers [47, 48, 49, 60, 63, 64, 78, 102, 103] in Russian).

The important advantage of the T-matrix method is its natural adaptation to the problems of the multi-scattering wave theory [331, 468, 469, 511, 471, 480, 481, 482, 485, 486, 487], radiative transfer equations [60, 472, 473], scattering by cluster of particles [195, 353, 354, 355, 362], particles of irregular shape [193] and Chebyshev T_n-particles [503], Raman scattering [188], extinction by polydisperse and polymorphic metal zoles [102, 103, 282, 283] and so on. Thus, the T-matrix approach is practically universal for all application fields of the light scattering theory. Concluding the discussion of this method, we insistently refer a reader to the reviews [362, 483] where the exhausted literature on the theory and applications of the T-matrix method is collected.

Part II. Approximate methods

6 Rayleigh and Rayleigh–Gans–Stevenson approximations

The main ideas of all the approximate methods are related to certain regions of the values of the basic diffraction parameters – the size parameter ka and the relative refractive index $m = n/n_0$. For instance, if $ka \ll 1$ and $ka|m| \ll 1$, one has the Rayleigh scattering [418, 419, 421] when the particle can be interpreted as an elementary dipole whose polarizability can be evaluate from the electrostatic equations. Apparently, Love [330] was first who paid attention to the fact that the solution for a small sphere is identical to the Hertz oscillator. The possibility to use the electrostatic approximation to calculate the polarizability allows one to consider practically any shape scatterers – from the regular ones (ellipsoid, cylinder, disc) [7, 274] to those with an arbitrary shape, structure and anisotropy [308, 309, 313, 405] (in the last case the polarizability tensor should be found numerically) – using the theory of the Rayleigh scattering.

The accuracy of the Rayleigh approximation for spheres was most carefully investigated in [303]. Because of its simplicity this approximation was utilized in a huge number of works to estimate the influence of the optical, geometrical and morphological parameters of particles on their scattering and extinction characteristics [7, 11, 25, 124]. Typical examples are the papers on estimates of the extinction spectra of disperse systems of small particles [161, 205, 207, 208, 231, 273, 427, 431]. The Rayleigh approximation is one of the main approaches in the theory of light scattering by gases, liquids and solutions in the regions distant from the critical points [18, 26, 130]. It should be noted that in the literature the terms including the name of Rayleigh (Rayleigh scattering, Rayleigh line, etc.) are often applied to quite different physical phenomena. We refer a reader to the paper of Yung [509] where this question is discussed in detail.

In 1953 A.F. Stevenson in two papers [458, 460] generalized the Rayleigh theory, using the expansions of the fields in terms of ka. For non-absorbing particles, the Rayleigh term is proportional $(ka)^2$, and the next one found in the general case by Stevenson is proportional to $(ka)^4$. For some simple shapes (ellipsoid, thin disc, etc.) one gets explicit, but rather complicated formules (the generalization of the Stevenson theory for the case of inhomogeneous particles and some simplifications see in [488]). This theory is called in the literature the Rayleigh–Gans–Stevenson approximation (RGS) keeping in mind the paper of R. Gans on ellipsoids published in 1912 [224]. Note, however, that the principal questions of light scattering by small spheroids were in our opinion considered in the paper of Rayleigh [419]. Applications of the RGS theory to different light scattering problems including orientation effects can be found in [86, 94, 105, 235, 250, 251, 252, 376, 377, 409, 410, 459, 461] (see also the review in [100]).

7 Rayleigh–Debye–Gans approximation (RDG)

In a large number of important cases the relative refractive index of particles is close to 1. Such particles are called “optically soft”, and the corresponding approximation could be named that of optically soft particles. This approximation is in particular well applicable to scattering of X-rays and neutrons [56, 211, 238]. The condition $|m - 1| \ll 1$ is not sufficient for development of the theory since an important role is also played by the ratio of the size to the wavelength and the phase shift $\rho = 2ka(m - 1)$. The RDG approximation is applicable when two conditions are satisfied

$$|m - 1| \ll 1, \quad |\rho| \ll 1. \tag{1}$$

For the theory based on the assumption (1), there are a set of the names: Rayleigh–Gans [11], Rayleigh–Debye [274, 397], Rayleigh–Gans–Born [474], Rayleigh–Gans–Debye [78, 144, 409, 410], Rayleigh–Gans–Rokard [132], Rayleigh–Debye–Gans (RDG) [100, 462], Born (or the first Born) [56, 135] approximation. We believe that the term RDG is the most suitable for the following reasons. The basic ideas of the method including the derivation of successive approximations from the integral equation for the scattered field were formulated by Rayleigh in 1881 in the paper [418], and the expression for the scattering cross-section for a sphere was obtained by him in 1914 [416]. Independently of Rayleigh, in 1915 Debye [201] derived the general expression for the intensity of X-rays scattered by an ensemble of randomly oriented particles. Later the approach was applied by Debye to scattering by polymer solutions [200, 202] which was very important for development of this field [26, 130, 274]. The contribution of Gans is of course essentially smaller than those of Rayleigh and Debye as in his paper [223] he actually repeated the Rayleigh result for a sphere [416] (in the third time the same results was obtained by Rokard, see [124], p.249). An analog of the Rayleigh iterations in the quantum mechanics was developed in 1926 by M. Born [163]. This approach became very popular one in this field, and the name of Born is rightfully connected with this approximation. The name of Gans is reasonable to leave in the term the RDG theory just for the reason that due to van de Hulst [11] the term Rayleigh–Gans approximation became widespread, although he did not consider this term to be a good one.

The RDG approximation can be obtained in several ways [25, 124, 274, 441]. For instance, one can use the general integral relation expressing the field $\vec{E}_{\rm s}$ scattered in the direction $\vec{s} = \vec{k}_{\rm s}/k$ through the integral containing the tensor Green function for the vector Helmholtz equation $\Gamma(\vec{r}, \vec{r}')$ [56] and the field inside the particle $\vec{E}_{\rm i}$, and make the latter equal to the field of the incident wave $\vec{E}_0 \exp(i\vec{k}_0\vec{r})$. Another way is based on the physical interpretation of scattering as a result of interference of the fields of independent dipoles excited by the incident wave in the particle volume V. In both cases the scattered field can be represented as

$$\vec{E}_{\rm s} = \vec{A} \exp(ikr)/r \tag{2}$$

with the vector amplitude $\vec{A} = k^2(1 - \vec{s} \cdot \vec{s})\vec{E}_0 U(\vec{q})$, where $\vec{q} = \vec{k}_{\rm s} - \vec{k}_0$ in the scattering vector with the module $q = 2k\sin(\theta/2)$, $U(\vec{q})$ is the Fourier transform of the dielectric permittivity tensor (normalized by the volume of polarizability of an optically soft particle, $\eta(\vec{r}) = (\varepsilon(\vec{r}) - 1)/4\pi$). For homogeneous particles $U(\vec{q}) = \eta V G(\vec{q})$, where the interference function is

$$G(\vec{q}) = \frac{1}{V} \int \exp[i(\vec{k}_0 - \vec{k}_{\rm s})\vec{r}] d^3\vec{r}. \tag{3}$$

Thus, the polarization characteristics of this approximation do not differ from those of the Rayleigh approximation for optically soft particles, and the angular ones differ only by the interference function.

The interference functions for particles of several shapes can be obtained in the form of simple analytical expressions. Rayleigh got the formula for a sphere in the form of a series in [418] and using the cylindrical functions of the order 3/2 in [422]. He also derived the formula for an infinitely long cylinder in the case of normal incidence [418]. Finite cylinders were considered in the paper [217] and in the book of van de Hulst [7], prisms in [82, 364], ellipsoids in the papers of A.L. Patterson in 1939 [389] (Kerker [274] at p.484 wrongly cites the paper [366] as the first one). For spheroids, the formula for the interference function was obtained in [237, 238] and later in [426, 428, 447]. The RDG approximation can be easily generalized for inhomogeneous particles, in particular with the spherical symmetry of inhomogeneity [11, 135, 216], and for particles of arbitrary shape with the rotational symmetry [369]. The tables of the interference functions see in [226, 274]. The papers [274, 444] suggest a small modification of the RDG where the wavenumber inside the particle takes into account the refractive index.

As one usually measures the intensity of scattered light from an ensemble of particles with a random orientation, the averaged square of the interference function $\langle G^2(q)\rangle = P(q)$ called the form-factor or Debye scattering form-factor (sometimes it is written simply as $G(q)$) has the practical interest. A detailed literature analysis of calculations of the form-factors for different models including polydisperse ensembles and polymer solutions is given in [100], and here we just list some investigations in this direction [82, 149, 150, 151, 152, 156, 197, 206, 225, 238, 245, 271, 274, 294, 296, 297, 298, 299, 335, 363, 364, 365, 366, 367, 378, 379, 381, 397, 398, 402, 426, 428, 445, 446, 465, 479]. The accuracy of the RDG approximation was estimated for spheres [197, 236, 274, 275, 475], cylinders [171, 438] and spheroids [144, 145, 297, 412, 475].

For anisotropic particles, the RDG theory was built in the assumption that the induced elementary dipoles are the product of the optical polarizability tensor and the incident field. In Eq. (2) the vector amplitude is not parallel to the incident field, and hence to describe the angular dependence of scattering one needs four Debye form-factors corresponding to four combinations of the polarizator and analyzator states relative to the planes of incidence and scattering ($P_{\rm vv}, P_{\rm vh}, P_{\rm hv}, P_{\rm hh}$, where the subscripts v and h have the common sense [384] and for a system with the random orientation $P_{\rm vh} = P_{\rm hv}$). Scattering by anisotropic spheres, cylinders, discs and spheroids was considered in [94, 96, 100, 130, 246, 255, 256, 261, 262, 375, 399, 406, 407, 408, 409, 410, 411, 415, 423, 479]. After the pioneer work [457] a large attention in the literature on polymers is paid to the scattering by specific anisotropic structures – so called spherulites [4, 5, 403, 429, 456].

The extinction cross-section in the RDG approximation is proportional to the volume and in general case does not differ in form from the extinction cross-section in the Rayleigh approximation. The scattering cross-section should be found from integration of the intensity over all solid angles, since the optical theorem in the RDG approximation gives either the extinction cross-section or 0 (for non-absorbing particles). The first calculations of the RDG scattering cross-section for the spheroidal model of bacteria cells were performed by in 1961 by A.L. Koch [295]. A systematic study of the integral functions in the method of the turbidity spectrum of spheroidal particles (the scattering cross-section and wave exponent [334] was made in [100, 104, 116, 118, 119, 120]. These works contain the general integral representations, results of numerical computations and asymptotic analytic expressions found for the region of small sizes and the intermediate region between the RDG and anomalous diffraction theories as well as in the cases of weak and strong eccentricity. Later the analysis of the integral characteristics of RDG–spheroids was also made in [44, 49, 53, 75].

8 Generalizations of the RDG approximation

For non-spherical isotropic particles, the classic variant of the RDG approximation does not include the anisotropy of the shape and hence does not give the correct Rayleigh limit, say, for small ellipsoids. Nevertheless, we have discussed above the works on anisotropic particles where the optical anisotropy was involved in the RDG theory, but implicitly assumed that the anisotropy was connected only with the anisotropy of the material. There are obviously possibilities a bit to improve the RDG approximation for isotropic non-spherical particles if to use a plane wave with a quasi-static (electrostatic) amplitude as the internal field. We call this variant a modified RDG approximation (MRDG). The idea of such a modification comes back to the work of K.S. Shifrin [124], who developed the iteration method of solution of the integral equation for an effective field and got a generalized version of the RDG with an exact Rayleigh limit for spherical particles. In 1956 R. Burberg [173] and A.V. Shatilov [121, 122] apparently were first who applied the MRDG to scattering by thin cylinders and spheroids, respectively. This variant of the theory was used in the works of J.-C. Ravey [406, 407, 408, 409, 410, 411] on light scattering by ordered disperse systems and in our papers [96, 100] to calculate the Mueller matrix (see also the recent paper [92] on the same topics) and in the theory of dichroism [97, 101, 108, 113].

The quasistatic extension of the RDG was criticized by Stoylov and Stoimenova [462], but in our opinion that was groundless. First, the MRDG leads to the correct Rayleigh limit. Second, Ravey [409] demonstrated the coincidence of the results of the MRDG and the exact RGS approximation (in the small size domain) for extremely eccentric particles. At last the MRDG approximation was recently derived by V.G. Farafonov [89] as the limit of the rigid solution for strongly eccentrical spheroids[1]. Thus, the paper [89] in fact closes the discussion on justification of the MRDG.

The second approach to generalization of the RDG is connected with the use of the Born iterations for the scattering integral equation [95, 124, 132, 264]. We say about the second Born approximation which is also called the second approximation in Shifrin's method [132, 292]. The first attempt of Y. Ikeda in 1963 [264] to apply this approach to non-spherical particles led to tedious results which did not find further application. In 1976 Ch. Acquista [132] made the Fourier transformation of the second approximation and obtained more compact formules as well as numerical results for spheres. In [95] we got a rigid integral equation for the scattering amplitude already in the complex Fourier space and then made its iterations. This approach was generalized for anisotropic particles in our works [97, 101, 285]. A method to increase the convergence of the Born iterations was suggested in [291]. Applications of the second approximation to different tasks see in [97, 101, 106, 109, 174, 191, 203, 204, 239, 240, 241, 253, 284, 285, 287, 292, 386, 461, 489]. For ensembles of non-spherical irregular particles, a new statistical approach within the RDG theory was suggested by K.S. Shifrin and I.A. Mikulinski [126, 443]. In a recent review [162] the importance of this approach was especially pointed out (though without references to the papers [126, 443]). In [185] the problem of light scattering by irregular particles was considered using a modified Mie theory (see also modelling of the Mueller matrix for irregular particles using the Mie theory in [254, 394]).

9 Anomalous diffraction approximation (AD)

Using the Huygens and Babinet principles van de Hulst [11] considered the problem of light scattering and extinction by a particle having the size $a \gg \lambda$ and the refractive index $m \sim 1$. The expression for the scattering amplitude in the small angle region obtained by van de Hulst is a generalization of the Fraunhofer diffraction formula and allows one to find the extinction cross-section from the optical theorem [11, 56]

$$C_{\rm ext} = 2{\rm Re} \int [1 - \exp(-i\rho(z))] dS, \tag{4}$$

where $\rho(z)$ is the phase shift of a ray propagating along the z-axis, and integration is over all the rays intersecting the particle. The absorption cross-section is

$$C_{\rm abs} = \int [1 - \exp(-2{\rm Im}\rho(z))] dS. \tag{5}$$

The range of applicability of the anomalous diffraction theory for the scattering amplitude is limited by small angles, however the formules for the cross-sections became good approximations for a wide class of particles. The AD approximation can be easily applied to non-spherical particles, which to some extent explains its popularity. The formules for scattering and extinction cross-sections for a spheroid were first derived by J.M. Greenberg in 1960 [232]. A simple method based only on the geometric consideration and using no complicated integrations in derivation of the extinction and absorption expressions was suggested in [79, 80] (the same problem was later considered in [259]). Another approach was earlier developed in [170]. The extinction cross-section in the general case of ellipsoids

[1]In this paper at p.867 the discussion of our paper [96] and that of Seker (see reference [10] in [89]) makes the impression that we and Seker utilized the erroneous decomposition of the quasistatic field using the unit vectors of the spherical system instead of the spheroid axes, which is not correct.

is given in [84] (the same result was obtained later again in [49, 51]). The integral cross-section for a cylinder was derived first in [194] (the same problem was considered in [68, 290, 292, 293, 438]). In frame of the AD approximation one also studied the integral characteristics of inhomogeneous particles: core-mantle [22, 30, 100] and multi-layered [178] spheres (including non-concentric particles [49]), multi-layered spheroids [29] as well as the particles with ledges [320] and cavities [321]. In [186, 187] the theorem of summation of the cross-sections within the AD was derived and the formula for prisma-like particles was obtained.

Detailed studies of the scattering coefficient and wave exponent of disordered spheroidal particles including numerical calculations and analytic asymptotics for large and small phase shifts and the limit cases of the eccentricity values were performed in [80, 81, 100, 104, 117, 119, 120, 129] and later in [43, 44, 49, 51, 53, 65, 66, 85].

Studies of the optical characteristics of polydisperse systems of spherical particles using the AD approximation was published in early works of K.S. Shifrin and his coauthors[2] and in the papers of V.N. Lopatin and coauthors [45, 48, 49].

In 1969 F.D. Bryant and P. Latimer [170] suggested to use the ratio of the volume to averaged cross-section as a size parameter for disordered spheroids and the corresponding phase shift parameter. Similarly, for polydisperse systems A.P. Prishivalko (see, e.g., [69, 70] and references in [127]) used a generalized size parameter equal to the ratio of the mean volume to the mean surface area. Both these ideas were utilized in the papers of V.N. Lopatin and his coauthors ("optical equivalence principle") [45, 48, 49, 52] and further developed as a general approach by L.E. Paramonov (small-parameter estimates of the integral cross-sections) [58, 60, 62].

The accuracy of the AD approximation in description of extinction and absorption of light by different scatterers was investigated in a number of works (see, e.g., the books [11, 23, 49, 123] and references therein). The general conclusion is that for the systems of optically soft particles the AD approximation qualitatively correctly shows all main laws of extinction, except for several minor features related to orientation, etc. [49]. Attempts to improve the AD approximation in the case of optically not very soft particles were undertaken in [244, 293, 370], but without success. This problem for spherical particles was solved by A.Ya. Perelman [390, 391] after a sophisticated mathematical analysis of the Mie series, for cylinders a similar problem was solved in [439].

10 WKB and eikonal approximations (high energy – HEA)

The approaches mentioned in the section title belong to one family which is called in Newton's book [56] the short waves or high energy approximation (HEA). It means the scattering by soft particles (or potentials) in the case of the wavelengths short in comparison with the particle size (or correspondingly the case of scattering of high energy particles by the potentials). In a certain sense these approaches are a generalization of the AD theory.

The Wentzel–Kramers–Brillouin (WKB) method was suggested first in optics by Rayleigh [420], but systematically used and got its name in the quantum mechanics [56, 292, 442]. The WKB approximation can be considered as a modification of the RDG theory, where in the interference integral (3) besides the geometrical phase difference one also includes the change of the phase of a ray on its path in the particle to the scattering element. This leads to an increase of the particle size region in calculations of the angular intensity, but only for small angles. On the other side, the application of the optical theorem to the WKB amplitude of the forward scattering gives the formula of the AD up to a factor $\frac{2}{m+1}A(0)_{\rm WKB} = A(0)_{\rm AD}$ [56, 292].

[2]See the references in [123] and the list of the further works of this group in the thesis of S.Yu. Shcheglov [127].

In the eikonal approximation the field inside the particle is also approximated by the plane wave with the phase shift which is proportional to $(m^2 - 1)$ and hence differs from the WKB phase shift only by the factor $(m+1)/2$. The eikonal approximation formula for the scattering amplitude can be slightly modified and represented in the form suggested by Glauber [56], i.e. as an integral over the impact parameters. This approach was used in light scattering by small particles in the works of T.W. Chen [176, 177, 178, 179] and of the French group [164, 166, 167, 180, 392, 393] to increase the angle region where one can calculate the intensity of scattered radiation. The eikonal approximation was also useful in solution of the problem of multiple scattering in media with large-scale inhomogeneities [1, 2, 9, 10, 77].

The main disadvantage of all versions of the short wave (AD, WBK, eikonal, etc.) approximation consists of their scalar nature and ignoring the wave polarization (an attempt [393] to get the vector generalization of the eikonal approximation can be hardly called successful). The generalization of the AD theory for anisotropic particles suggested in 1979 by G. Meeten [338] and used in [337, 339, 340, 341, 502, 513] and our works [101, 112, 115, 284, 288] is applicable only to the optically soft particles, but in the isotropic case this approximation is reduced again to a scalar variant. In this connection a particular interest is deserved by a recent pioneer work [10] where the eikonal approximation principles are applied to solution of the complicated problem of multiple scattering of electromagnetic waves in a medium with large-scale anisotropic inhomogeneities.

11 Geometrical optics approximation (GO)

For particles of very large sizes, scattering can be considered as a result of interference of the rays having multiple reflections and refractions according to the laws of geometrical optics. Diffraction at the particle edges which gives a sharp maximum in the region of small angles can be taken into account separately. The formulation of general principles, computational schemes and discussion of obtained results within the GO can be found in books [7, 11, 124]. The papers [413, 414] presented a method where the scattering field was expressed via the field at the particle surface using the Huygens–Kirchhoff principle, and reflection and refraction laws were employed to find the unknown field (the approach was called physical optics approximation). Utilizing the GO method the author of [184] solved the general question why the mean extinction cross-section for an ensemble of large non-spherical particles is always larger than this cross-section for equivolume spheres. Illustrations of various applications of the method are given in [28, 30, 155, 192, 263, 412, 425, 427]. Note also a recent paper [242] where the GO method is applied to analysis of light scattering by spheres with the size parameter $ka = 500$ and the discovered theoretical and experimental relationships in the oscillation of s and p components of intensity were used for successful solution of the inverse problem of sizing. The accuracy of the GO method for non-spherical particles was studied in a recent paper [332] by comparison with the exact T-matrix method results.

12 Perturbation method

The perturbation method is based on the small-parameter expansion of an unknown solution of the light scattering problem in a vicinity of the exact solution. In application to non-spherical particles it means that one searches for a solution in the form of small deviations from the Mie solution caused by small deviations of the particles shape from a sphere. The first solution of this kind was obtained in 1960 by T. Oguchi [383] (the often cited paper [507] appeared 4 years later). The general approach to solution of the problem by the perturbation method was developed in 1969 by V.A. Erma [213] (see also the papers [212, 289, 372, 373] on concrete applications of the method and recent paper [12]).

With the development of more efficient algorithms for non-spherical particles the perturbation methods lost its meaning. The only probably exclusion is the case of anisotropic particles for which the rigid solution is either impossible or too complicated. For such problems the perturbation method can give information of the first approximation, which is important for understanding of the basic principles of influences of the material anisotropy. A good illustration here is a large number of investigations made by the Minsk group of A.P. Prishivalko for weakly anisotropic spheres [32, 33, 35, 36, 37, 38, 39, 40, 72]. As the basic solution of this problem, one takes the Mie solution for an average refractive index, and the anisotropy is represented by small deviations from it. More details can be found in the book [72].

13 Hybrid and simple analytical approximations

Latimer [322, 323] suggested the approximations based on a combination of the RDG and AD theories for spheroids and the Mie theory to describe scattering and extinction of light by non-spherical particles. The idea of these approximations is as follows: on the base of the RDG and AD theories to find an analogy between the formulas for the scattering characteristics for a sphere and an oriented spheroid. From this analogy one postulates a certain relationship between the radius and refractive index of an "equivalent" sphere from one side, and the spheroid parameters (including the orientation) from another side. Then the scattering by a spheroid or an ensemble of spheroids is replaced by scattering by the "equivalent" sphere calculated from the Mie theory. Such approximations are useful as simplified computational algorithms, though do not have rigorous enough physical justifications. In certain sense such a method is analogous to a more pragmatic approach when the exact formulas or results of calculations are approximated by simple approximate analytic expressions. For example, such approach was used both for approximation of formulas of the Mie theory [20, 73, 128, 214, 229, 247, 248, 249, 492, 512] and for description of scattering by spheroids [218] and cylinders [437, 438, 439].

References

[1] Adzhemyan L., Vasil'ev A.N., Perekalin M.M. Uglovaya zavisimost' rasseyaniya neobyknovennogo lucha v nematicheskih zhidkih kristallah. Opt. Spektr., 1993, v.74, p.1143–1154.

[2] Adzhemyan L., Vasil'ev A.N., Perekalin M.M., Rejttu H.Yu. O proishozhdenii dvuh harakternyh dlin pri rasprostranenii sveta v nematikah. Opt. Spektr., 1990, v.69, p.640–645.

[3] Barabanenkov Yu.N. Mnogokratnoe rasseyanie voln na ansamble chastits i teoriya perenosa izlucheniya. Uspekhi Fiz. Nauk, 1975, v.117, p.49–78.

[4] Baranov V.G. Rasseyanie polyarizovannogo sveta ot polimernyh sistem, soderzhashchih sferolity. Vysokomolek. soed., 1966, v.8, p.2117–2124.

[5] Baranov V.G. Polyarizatsionno-difraktometricheskie issledovaniya strukturnyh prevrashchenij v kristallizuyushchihsya polimerah. Dissert. dokt. f.-m. nauk, L.: IVC AN SSSR, 1973.

[6] Baran Sh., Gregori D. Flokulyatsiya suspenzij kaolina kationnymi polie'lektrolitami. Kolloid. zhurn., 1996, v.58, p.13–18.

[7] Bohren C., Huffmen D. Absorption and scattering og light by small particles. 1983, J.Wiley & Sons, New York.

[8] Vasil'ev E.N., Il'inskij A.S., Sveshnikov A.G. Chislennye metody resheniya zadach difraktsii na lokal'nyh neodnorodnostyah in Sb. rabot vychislitel'nogo tsentra Moskovskogo universiteta, 1975, v.24, p.3–23.

[9] Val'kov A.Yu., Romanov V.P. Osobennosti rasprostraneniya i rasseyaniya voln v sredah s anomal'no krupnomasshtabnymi sluchajnymi neodnorodnostyami. ZhETF, 1991, v.99, p.1283–1301.

[10] Val'kov A.Yu., Tipyasova T.I. Uglovye i polyarizatsionnye harakteristiki intensivnosti mnogokratnogo rasseyaniya v izotropnoj srede s krupnomasshtabnymi anizotropnymi neodnorodnostyami. Opt. Spektr., 1995, v.79, p.125–133.

[11] van de Hulst H. Light scattering by small particles. 1957, J.Wiley & Sons, NY.

[12] Volchkov N.G., Kavach V.Yu. Rasseyanie e'lektromagnitnyh voln slaboasimmetrichnymi chastitsami nepravil'noj formy. Izv. AN SSSR, ser. FAO, 1992, v.28, p.158–165.

[13] Voshchinnikov N.V. Opticheskie svojstva sferoidal'nyh pylinok. Pryamo proshedshee izluchenie. Astron. Zhurn., 1990, v.67, p.1061–1073.

[14] Voshchinnikov N.V., Farafonov V.G. Rasseyanie sveta die'lektricheskimi sferoidami.I. Opt. Spektr., 1985, v.58, p.135–141.

[15] Voshchinnikov N.V., Farafonov V.G. Rasseyanie sveta die'lektricheskimi sferoidami. II. Vestn. LGU, 1985, N8, p.81–91.

[16] Voshchinnikov N.V., Farafonov V.G. Rasseyanie sveta die'lektricheskimi sferoidami. III. Opt. Spektr., 1985, v.59, p.1250–1254.

[17] Voshchinnikov N.V., Farafonov V.G. Rasseyanie sveta die'lektricheskimi sferoidami. IV. Opt. Spektr., 1986, v.60, p.1026–1030.

[18] Vuks M.F. Rasseyanie sveta v gazah, zhidkostyah i rastvorah. L.: Izd-vo LGU, 1977.

[19] Granovskij Ya.I. Faktor oslableniya pri rasseyanii sveta prozrachnymi chastitsami. ZhETF, 1994, v.105, p.1199–1207.

[20] Dejrmendzhan D. Rasseyanie e'lektromagnitnogo izlucheniya polidispersnymi chastitsami. M.: Mir, 1971.

[21] Eremin Yu.A., Orlov N.V., Rozenberg V.I. Analiz protsessov rasseyaniya voln na sovokupnosti chastits. Opt. Spektr., 1993, v.75, p.115–122.

[22] Zege E.P., Kohanovskij A.A. K priblizheniyu anomal'noj difraktsii dlya dvuhslojnyh sharov. Izv. AN SSSR, ser. FAO, 1989, v.25, p.1195–1201.

[23] Zuev V.E. Rasprostranenie vidimyh i infrakrasnyh voln v atmosfere. M.: Sov. radio, 1970.

[24] Il'inskij A.S., Pavlov A.A., Sveshnikov A.G. Issledovanie nekotoryh zadach difraktsii chislennymi metodami. L.: Izd-vo LGU, 1972.

[25] Isimaru A. Rasprostranenie i rasseyanie voln v sluchajno–odnorodnyh sredah. M.: Mir, 1981.

[26] Klenin V.I. Termodinamika sistem s gibkotsepnymi polimerami. Saratov: Izd-vo SGU, 1995.

[27] Komarov I.V., Ponomarev L.I., Slavyanov S.Yu. Sferoidal'nye i kulonovskie sferoidal'nye funktsii. M.: Nauka, 1976.

[28] Kohanovskij A.A. Integral'nye harakteristiki rasseyaniya sveta sfericheskimi vklyucheniyami s otnositel'nym pokazatelem prelomleniya, men'shim edinitsy. Opt. Spektr., 1989, v.67, p.165–168.

[29] Kohanovskij A.A. Pogloshchenie i rasseyanie sveta krupnymi sloistymi e'llipsoidal'nymi chastitsami. Opt. Spektr., 1991, v.71, p.351–354.

[30] Kohanovskij A.A. Rasseyanie sveta krupnymi dvuhslojnymi chastitsami: geometroopticheskaya asimptotika. Izv. AN SSSR, ser. FAO, 1990, v.26, p.949–954.

[31] Kuz'min V.N. Zakonomernosti v oslablenii sveta sistemami sil'no vytyanutyh chastits // III Vsesoyuznoe soveshchanie po rasprostraneniyu lazernogo izlucheniya v dispersnoj srede. Tezisy dokladov. Obolensk, 1985, p.147–149.

[32] Kuz'min V.N. Linejnyj dihroizm rasseivayushchih sistem iz anizotropnyh nepogloshchayushchih chastits. Zhurn. prikl. spektr., 1981, v.35, p.929–931.

[33] Kuz'min V.N. Matritsa rasseyaniya e'lektromagnitnyh voln na sfericheskih anizotropnyh chastitsah. Izv. AN BSSR, 1980, N4, p.69–76.

[34] Kuz'min V.N. Osobennosti e'lementov matritsy rasseyaniya sistem sil'no vytyanutyh chastits // III Vsesoyuznoe soveshchanie po rasprostraneniyu lazernogo izlucheniya v dispersnoj srede. Tezisy dokladov. Obolensk, 1985, p.150–153.

[35] Kuz'min V.N. Sootnoshenie Bugera dlya anizotropnyh rasseivayushchih sred // II Vsesoyuznoe soveshchanie po rasprostraneniyu lazernogo izlucheniya v dispersnoj srede. Moskva: Gidrometeoizdat, 1982, p.193–195.

[36] Kuz'min V.N. Spektral'naya prozrachnost' sistem anizotropnyh kvartsevyh chastits. Zhurn. prikl. spektr., 1981, v.35, p.1024–1028.

[37] Kuz'min V.N., Babenko V.A. Nekotorye zakonomernosti povedeniya uglovyh harakteristik rasseyaniya sveta kristallicheskimi chastitsami v priblizhenii slaboj anizotropii. Zhurn. prikl. spektr., 1982, v.36, p.305–309.

[38] Kuz'min V.N., Babenko V.A. Rasseyanie sveta slaboanizotropnoj sfericheskoj chastitsej. Opt. Spektr., 1981, v.50, p.498–505.

[39] Kuz'min V.N., Oshchepkov S.L., Prishivalko A.P. K interpretatsii harakteristik svetorasseyaniya ae'rozol'nyh sred iz anizotropnyh chastits s pomoshch'yu model'nyh sistem odnorodnyh sfer. Izv. AN SSSR, ser. FAO, 1984, v.20, p.280–286.

[40] Kuz'min V.N., Prishivalko A.P. Ob osobennostyah prohozhdeniya sveta cherez dispersionnyj fil'tr s napolnitelem iz anizotropnyh chastits. Zhurn. prikl. spektr., 1984, v.41, p.268–272.

[41] Lebedeva V.N. Raschet rasseyaniya i pogloshcheniya IK-izlucheniya chastitsami zolota tsilindricheskoj formy. Opt. Spektr., 1972, v.32, p.772–777.

[42] Lebedeva V.N. Raschet rasseyaniya i pogloshcheniya sveta tsilindricheskimi chastitsami. Opt. Spektr., 1972, v.32, p.1010–1014.

[43] Lopatin V.N. O rasseyanii izlucheniya bol'shimi sferoidal'nymi chastitsami v oblasti Releya-Gansa. Izv. AN SSSR, ser. FAO, 1987, v.23, p.264–268.

[44] Lopatin V.N. Ob otsenke asimptoticheskih formul poperechnika svetorasseyaniya RGD-chastits. Opt. Spektr., 1988, v.64, p.426–428.

[45] Lopatin V.N. Pogloshchenie izlucheniya polidispersnymi vzvesyami sfericheskih chastits. Opt. Spektr., 1989, v.66, p.665–668.

[46] Lopatin V.N. Rasseyanie i oslablenie sveta dvuhslojnymi i trehslojnymi sharami - modelyami kletok. Dissert. kand. f.-m. nauk, Krasnoyarsk: In–t fiziki SO AN SSSR, 1977.

[47] Lopatin V.N., Paramonov L.E. Issledovanie matrits i poperechnikov rasseyaniya sveta gorizontal'no i haotichno orientirovannyh "myagkih" chastits. Izv. AN SSSR, ser. FAO, 1989, v.25, p.608–615.

[48] Lopatin V.N., Paramonov L.E. . Matematicheskoe modelirovanie opticheskih harakteristik vzvesej "myagkih" chastits i ih svyaz' s osnovnymi formiruyushchimi faktorami. in Rasseyanie i pogloshchenie sveta v prirodnyh i iskusstv. dispersnyh sredah. Pod red. A.P. Ivanova. Minsk: In-t fiziki AN BSSR, 1991, p.195–214.

[49] Lopatin V.N., Sid'ko F.Ya. Vvedenie v optiku vzvesej kletok. Novosibirsk: Nauka, 1988.

[50] Lopatin V.N., Sid'ko F.Ya. Vliyanie obolochki na oslablenie i rasseyanie sveta sfericheskimi trehslojnymi chastitsami-modelyami kletok. Opt. Spektr., 1977, v.43, p.930–935.

[51] Lopatin V.N., Sid'ko F.Ya. Oslablenie e'lektromagnitnogo izlucheniya bol'shimi "myagkimi" e'llipsoidami. Opt. Spektr., 1986, v.61, p.430–432.

[52] Lopatin V.N., Sid'ko F.Ya. Svetorasseyanie vzvesej haotichno i preimushchestvenno orientirovannyh sferoidov v koordinatah obobshchennogo parametra. Opt. Spektr., 1988, v.64, p.1328–1331.

[53] Lopatin V.N., Sid'ko F.Ya. Ob otsenke svetorasseivatel'nyh i pogloshchatel'nyh svojstv vzvesej "myagkih" sferoidal'nyh chastits v priblizhenii Releya-Gansa i anomal'noj difraktsii. Izv. AN SSSR, ser. FAO, 1987, v.23, p.742–751.

[54] Mishchenko M.I. Raschet integral'nyh harakteristik svetorasseyaniya dlya ansamblya haoticheski orientirovannyh nesfericheskih chastits. Kinem. fiz. neb. tel, 1990, v.6, p.95–96.

[55] Mors F.M., Feshbah G. Metody teoreticheskoj fiziki. M.: IL, 1958.

[56] N'yuton R. Teoriya rasseyaniya voln i chastits. M.: Mir, 1969.

[57] Paramonov L.E. K identifikatsii biologicheskih chastits. Opt. Spektr., 1994, v.76, p.471–474.

[58] Paramonov L.E. Maloparametricheskie modeli otsenki sechenij oslableniya, rasseyaniya i pogloshcheniya atmosfernyh ae'rozolej. Opt. Atmosf. Okeana, 1994, v.7, p.1139–1148.

[59] Paramonov L.E. Matritsa Myullera ansamblya chastits proizvol'noj formy s proizvol'noj kvadratichno integriruemoj funktsiej raspredeleniya po orientatsiyam. Opt. Spektr., 1994, v.77, p.911–920.

[60] Paramonov L.E. Metod T-matrits i kvantovaya teoriya uglovogo momenta v zadachah rasseyaniya i pogloshcheniya sveta ansamblyami chastits nesfericheskoj formy. Dissert. dokt. f.-m. nauk, Tomsk: In-t opt. atm. RAN, 1995.

[61] Paramonov L.E. Obobshchennoe reshenie Mi dlya sfokusirovannogo puchka. Opt. Spektr., 1993, v.6, p.1404–1410.

[62] Paramonov L.E. Otsenka secheniya pogloshcheniya polidispersnyh haoticheski orientirovannyh slaboprelomlyayushchih e'llipsoidal'nyh chastits. Opt. Spektr., 1995, v.78, p.964–966.

[63] Paramonov L.E., Lopatin V.N. Ob uglovoj zavisimosti matritsy rasseyaniya vzvesi "myagkih" sferoidal'nyh chastits. Opt. Spektr., 1989, v.66, p.164–166.

[64] Paramonov L.E., Lopatin V.N., Sid'ko F.Ya. O vliyanii asferichnosti orientirovannyh "myagkih" chastits polidispersnoj vzvesi na e'lementy ee matritsy rasseyaniya sveta. Opt. Spektr., 1989, v.66, p.400–408.

[65] Paramonov L.E., Lopatin V.N., Sid'ko F.Ya. O zavisimosti pogloshchatel'noj sposobnosti myagkih sferoidal'nyh chastits ot ih formy i orientatsii. Opt. Spektr., 1986, v.60, p.360–364.

[66] Paramonov L.E., Lopatin V.N., Sid'ko F.Ya. O svetorasseyanii "myagkih" sferoidal'nyh chastits. Opt. Spektr., 1986, v.61, p.570–576.

[67] Perel'man A.Ya. Difraktsiya na sfericheski simmetrichnyh neodnorodnyh rasseivatelyah. Opt. Spektr., 1995, v.78, p.822–831.

[68] Petrushin A.G. Rasseyanie i oslablenie izlucheniya "myagkimi" tsilindrami konechnoj dliny. Opt. Spektr., 1983, v.54, p.882–884.

[69] Prishivalko A.P. O svyazi pokazatelej oslableniya i rasseyaniya sveta s parametrami mikrostruktury polidispersnoj rasseivayushchej sredy. Izv. AN SSSR, ser. FAO, 1973, v.9, p.552–556.

[70] Prishivalko A.P. Opredelenie parametrov funktsii raspredeleniya po razmeram i kontsentratsii chastits iz izmerenij pokazatelej oslableniya i obratnogo rasseyaniya. Zhurn. prikl. spektr., 1973, v.19, p.320–331.

[71] Prishivalko A.P., Babenko V.A. Rasseyanie sveta sistemami radial'no-neodnorodnyh chastits. Izv. AN SSSR, ser. FAO, 1979, v.15, p.710–716.

[72] Prishivalko A.P., Babenko V.A., Kuz'min V.N. Rasseyanie i pogloshchenie sveta neodnorodnymi i anizotropnymi sfericheskimi chastitsami. Minsk: Nauka i tehn., 1984.

[73] Ramazanov K.R., Khlebtsov N.G., Shchegolev S.Yu., Klenin V.I. Harakteristicheskie funktsii svetorasseyaniya polidispersnyh sistem. Kolloid. zhurn., 1983, v.45, p.473–479.

[74] Ramm A.G. Matritsa rasseyaniya sveta na maloj chastitse proizvol'noj formy. Opt. Spektr., 1974, v.37, p.125–129.

[75] Ivanov A.P. (red.) Rasseyanie i pogloshchenie sveta v prirodnyh i iskusstvennyh dispersnyh sredah. Minsk: In-t fiziki AN BSSR, 1991.

[76] Rozenberg V.I. Rasseyanie i oslablenie e'lektromagnitnogo izlucheniya atmosfernymi chastitsami. L.: Gidrometeoizdat, 1972.

[77] Rytov S.M., Kravtsov Yu.A., Tatarskij V.I. Vvedenie v statisticheskuyu radiofiziku. M.: Nauka, 1978.

[78] Sid'ko F.Ya., Lopatin V.N., Paramonov L.E. Polyarizatsionnye harakteristiki vzvesej biologicheskih chastits. Novosibirsk: Nauka, 1990.

[79] Sirota A.I., Khlebtsov N.G. . Opticheskie mehanizmy e'lektroopticheskih e'ffektov v kolloidah in Fizika prochnosti, plastichnosti metallov i e'lektrodinamicheskie yavleniya v veshchestve. Kujbyshev: Izd-vo Kujb. polit. in-ta, 1976, p.139–153.

[80] Sirota A.I., Khlebtsov N.G. Opticheskie mehanizmy e'lektroopticheskih yavlenij v dispersnyh sistemah. 1. Oslablenie sveta proizvol'no orientirovannym sferoidom. Opt. Spektr., 1980, v.48, p.796–801.

[81] Sirota A.I., Khlebtsov N.G. Opticheskie mehanizmy e'lektroopticheskih yavlenij v dispersnyh sistemah. 2. Modulyatsiya sveta polem P-impul'sov. Opt. Spektr., 1980, v.48, p.936–943.

[82] Slutsker A.I., Marihin V.A. Nekotorye voprosy rasseyaniya e'lektromagnitnogo izlucheniya na submikroskopicheskih chastitsah nepravil'noj formy. Opt. Spektr., 1961, v.10, p.232–239.

[83] Stretton J.A. Teoria elektromagnetizma. M.: Gostehizdat, 1948.

[84] Suhacheva V.I., Tvorogov S.D. Koe'ffitsient oslableniya sveta sistemoj haoticheski orientirovannyh e'llipsoidov. Izv. AN SSSR, ser. FAO, 1973, v.9, p.1320–1323.

[85] Terskov N.A. E'ffekty svetorasseyaniya, obuslovlennye asferichnost'yu komponentov biologicheskoj vzvesi. DAN SSSR, 1988, v.301, p.734–737.

[86] Tyabotov A.E., Shlyahov V.I., Shupyatskij A.B. Rasseyanie polyarizovannogo sveta e'llipsoidal'nymi chastitsami s parametrom rho¡1 i rho¿1 v storonu istochnika izlucheniya. Trudy Centr. aerolog. observ., 1975, v.109, p.30–43.

[87] Farafonov V.G. Difraktsiya ploskoj e'lektromagnitnoj volny na die'lektricheskom sferoide. Differents. uravn., 1983, v.19, p.1765–1777.

[88] Farafonov V.G. Difraktsiya polya dipolya na absolyutno provodyashchem sferoide. DAN SSSR, 1980, v.255, p.1088–1092.

[89] Farafonov V.G. Opticheskie svojstva sil'no vytyanutyh i splyusnutyh sferoidal'nyh chastits. Opt. Spektr., 1990, v.69, p.866–872.

[90] Farafonov V.G. Rasseyanie sveta sil'no vytyanutymi sferoidal'nymi chastitsami. Opt. Spektr., 1989, v.66, p.150–156.

[91] Farafonov V.G. Rasseyanie sveta sil'no splyusnutymi sferoidal'nymi chastitsami. Opt. Spektr., 1990, v.68, p.397–402.

[92] Farafonov V.G. Rasseyanie sveta sferoidal'nymi chastitsami v kvazistaticheskom priblizhenii. Opt. Spektr., 1994, v.77, p.455–458.

[93] Farafonov V.G. Rasseyanie sveta die'lektricheskimi sferoidal'nymi chastitsami. in Volny i difraktsiya. 8 Vsesoyuznyj seminar po difraktsii i rasprostraneniyu radiovoln. M., 1981, p.178–181yu

[94] Khlebtsov N.G. Analiz i chislennyj raschet matritsy rasseyaniya dlya "myagkih" sferoidov, sravnimyh s dlinoj volny sveta. Opt. Spektr., 1979, v.46, p.524–531.

[95] Khlebtsov N.G. Integral'noe uravnenie dlya zadach rasseyaniya sveta na chastitsah sredy. Opt. Spektr., 1984, v.57, p.658–662.

[96] Khlebtsov N.G. Matritsa rasseyaniya dlya anizotropnyh e'llipsoidov, sravnimyh s dlinoj volny sveta. Opt. Spektr., 1979, v.46, p.341–345.

[97] Khlebtsov N.G. Opticheskie e'ffekty v orientirovannyh dispersnyh sistemah. Preprint IBFRM AN SSSR N1, Saratov: Izd-vo SGU, 1988.

[98] Khlebtsov N.G. Oslablenie i rasseyanie sveta haoticheski orientirovannym ansamblem: tochnye resheniya v T-matrichnom podhode. Opt. Spektr., 1991, v.71, p.151–153.

[99] Khlebtsov N.G. Pogloshchenie i rasseyanie sveta fraktal'nymi klasterami bol'shoj massy. Opt. Spektr., 1993, v.75, p.670–677.

[100] Khlebtsov N.G. Rasseyanie sveta nesfericheskimi chastitsami v ego primenenii k metodu spektra mutnosti i e'lektroopticheskomu e'ffektu. Dissert. kand. f.–m. nauk, Saratov: SGU, 1980.

[101] Khlebtsov N.G. Teoriya dihroizma i dvojnogo lucheprelomleniya v aksial'no orientirovannyh dispersnyh sistemah. Preprint IBFRM AN SSSR N2, Saratov: Izd-vo SGU, 1988.

[102] Khlebtsov N.G., Bogatyrev V.A., Dykman L.A., Mel'nikov A.G. Opticheskie svojstva kolloidnogo zolota i ego konyugatov s biospetsificheskimi makromolekulami. Kolloid. zhurn., 1995, v.57, p.412–423.

[103] Khlebtsov N.G., Bogatyrev V.A., Dykman L.A., Mel'nikov A.G. . Spektral'nye svojstva kolloidnogo zolota. Opt. Spektr., 1996, v.80, p.128–137.

[104] Khlebtsov N.G., Klenin V.I., Frenkel' S.Ya. Uchet nesferichnosti chastits pri opredelenii parametrov dispersnyh sistem metodom spektra mutnosti. 7. Funktsii svetorasseyaniya dlya sistem sil'no anizodiametricheskih chastits. Opt. Spektr., 1978, v.45, p.1138–1143.

[105] Khlebtsov N.G., Kutuzov Yu.I. Uglovye funktsii svetorasseyaniya izotropnyh sferoidov v priblizhenii Releya-Gansa-Stivensona. Opt. Spektr., 1980, v.49, p.341–346.

[106] Khlebtsov N.G., Mel'nikov A.G. Dvojnoe lucheprelomlenie v dispersnyh sistemah, orientirovannyh vneshnim polem. Kolloid. zhurn., 1990, v.52, p.1147–1153.

[107] Khlebtsov N.G., Mel'nikov A.G. Integral'noe sechenie rasseyaniya i volnovoj eksponent fraktal'nyh klasterov. Kolloid. zhurn., 1993, v.55, p.123–131.

[108] Khlebtsov N.G., Mel'nikov A.G. Opticheskie e'ffekty v orientirovannyh dispersnyh sistemah. 1. Statsionarnyj dihroizm v aksial'no orientirovannyh dispersiyah melkih i krupnyh chastits. Opt. Spektr., 1989, v.67, p.389–394.

[109] Khlebtsov N.G., Mel'nikov A.G. Opticheskie e'ffekty v orientirovannyh dispersnyh sistemah. 4. Statsionarnaya teoriya DLP v dispersiyah s aksial'noj orientatsiej. Opt. Spektr., 1990, v.68, p.238–239.

[110] Khlebtsov N.G., Mel'nikov A.G. Spektral'naya prozrachnost' i volnovoj eksponent polidispersnogo ansamblya fraktal'nyh klasterov. Kolloid. zhurn., 1993, v.55, p.167–176.

[111] Khlebtsov N.G., Mel'nikov A.G. Strukturnyj faktor i eksponent rasseyaniya polidispersnyh reaktsionno-ogranichennyh fraktal'nyh klasterov. Opt. Spektr., 1993, v.75, p.123–129.

[112] Khlebtsov N.G., Mel'nikov A.G. Teoriya dvojnogo lucheprelomleniya v priblizhenii fizicheskoj optiki. Zhurn. prikl. spektr., 1989, v.50, p.977–983.

[113] Khlebtsov N.G., Mel'nikov A.G. Teoriya dihroizma orientirovannyh dispersij anizotropnyh chastits. Kolloid. zhurn., 1990, v.52, p.928–934.

[114] Khlebtsov N.G., Mel'nikov A.G. E'ffekty konechnogo razmera i polidispersnosti v rasseyanii sveta fraktal'nymi diffuzionno-ogranichennymi klasterami. Opt. Spektr., 1992, v.73, p.965–973.

[115] Khlebtsov N.G., Mel'nikov A.G., Bogatyrev V.A., Sirota A.I. Dihroizm orientirovannyh dispersij v priblizhenii fizicheskoj optiki. Zhurn. prikl. spektr., 1989, v.51, p.99–105.

[116] Khlebtsov N.G., Shchegolev S.Yu. Uchet nesferichnosti chastits pri opredelenii parametrov dispersnyh sistem metodom spektra mutnosti. 1.Harakteristicheskie funktsii svetorasseyaniya sistem nesfericheskih chastits v priblizhenii Releya-Gansa. Opt. Spektr., 1977, v.42, p.956–962.

[117] Khlebtsov N.G., Shchegolev S.Yu. Uchet nesferichnosti chastits pri opredelenii parametrov dispersnyh sistem metodom spektra mutnosti. 2. Harakteristicheskie funktsii svetorasseyaniya sistem nesfericheskih chastits v priblizhenii van de Hyulsta. Opt. Spektr., 1977, v.42, p.1152–1157.

[118] Khlebtsov N.G., Shchegolev S.Yu., Klenin V.I. Uchet nesferichnosti chastits pri opredelenii parametrov dispersnyh sistem metodom spektra mutnosti. 4. Primenenie zavisimosti volnovogo eksponenta ot razmera chastits v priblizhenii Releya-Gansa dlya obratnyh zadach. Opt. Spektr., 1977, v.43, p.292–296.

[119] Khlebtsov N.G., Shchegolev S.Yu., Klenin V.I. Uchet nesferichnosti chastits pri opredelenii parametrov dispersnyh sistem metodom spektra mutnosti. 5. Harakteristicheskie funktsii svetorasseyaniya sistem "myagkih" splyusnutyh chastits s haoticheskoj orientatsiej. Opt. Spektr., 1978, v.45, p.563–569.

[120] Khlebtsov N.G., Shchegolev S.Yu., Klenin V.I., Frenkel' S.Ya. Uchet nesferichnosti chastits pri opredelenii parametrov dispersnyh sistem metodom spektra mutnosti. 6. Obratnye zadachi dlya splyusnutyh chastits. Ustojchivost' metoda. Opt. Spektr., 1978, v.45, p.710–717.

[121] Shatilov A.V. O rasseyanii sveta die'lektricheskimi e'llipsoidami, sravnimymi s dlinoj volny sveta. I. Obshchee vyrazhenie dlya indikatrisy rasseyaniya e'llipsoidal'noj chastitsy. Opt. Spektr., 1960, v.9, p.86–91.

[122] Shatilov A.V. O rasseyanii sveta die'lektricheskimi e'llipsoidami, sravnimymi s dlinoj volny. II. Zavisimost' indikatrisy rasseyaniya ot razmerov, formy i orientatsii e'llipsoida. Koe'ffitsient rasseyaniya. Opt. Spektr., 1960, v.9, p.231–243.

[123] Shifrin K.S. Vvedenie v optiku okeana. L.: Gidrometeoizdat, 1983.

[124] Shifrin K.S. Rasseyanie sveta v mutnoj srede. M.: Gostehizdat, 1951.

[125] Shifrin K.S. Rasseyanie sveta na dvuhslojnyh chastitsah. Izv. AN SSSR, ser. Geofiz., 1952, N2, p.15–21.

[126] Shifrin K.S. Rasseyanie sveta sistemoj chastits v priblizhenii Releya-Gansa. Opt. Spektr., 1982, v.52, p.359–366.

[127] Shchegolev S.Yu. Issledovanie protsessov fazovogo razdeleniya razbavlennyh polimernyh sistem metodom spektroturbidimetricheskogo titrovaniya. Dissert. kand. f.-m. nauk, L.: IVS AN SSSR, 1983.

[128] Shchegolev S.Yu., Khlebtsov N.G. V Primen. mini- i makro-EVM pri opred. param. disp. sist. Pod red. V.V. Ignatova. Saratov: Izd-vo SGU, 1984.

[129] Shchegolev S.Yu., Khlebtsov N.G., Klenin V.I. Uchet nesferichnosti chastits pri opredelenii parametrov dispersnyh sistem metodom spektra mutnosti. 3. Obratnye zadachi. Opt. Spektr., 1977, v.43, p.151–156.

[130] Eskin V.E. Rasseyanie sveta rastvorami polimerov. L.: Nauka, 1986.

[131] Abushagur M.A.G., George N. Polarization and wavelength effects on the scattering from dielectric cylinders. Appl. Opt., 1985, v.24, p.4141–4145.

[132] Acquista Ch. Light scattering by tenuous particles: a generalization of the Rayleigh-Gans-Rocard approach. Appl. Opt., 1976, v.15, p.2932–2936.

[133] Aden A.L., Kerker M. Scattering of electromagnetic waves from two concentric spheres. J. Appl. Phys., 1951, v.22, p.1242–1246.

[134] Adey A.J. Scattering of electromagnetic waves by coaxial cylinders. Can. J. Phys., 1956, v.34, p.510–520.

[135] Albini F.A. Scattering of a plane wave by an inhomogeneous sphere under the Born approximation. J. Appl. Phys., 1962, v.33, p.3032–3036.

[136] Andreasen M.G. Scattering from bodies of revolution. IEEE Trans. Anten. Propag., 1965, v.AP-13, p.303–310.

[137] Andreasen M.G. Scattering from parallel metallic cylinders with arbitrary cross section. IEEE Trans. Anten. Propag., 1964, v.AP-12, p.746–754.

[138] Asano Sh. Light scattering by horizontally oriented spheroidal particles. Appl. Opt., 1983, v.22, p.1390–1396.

[139] Asano Sh. Light scattering properties of spheroidal particles. Appl. Opt., 1979, v.18, p.712–723.

[140] Asano Sh., Sato M. Light scattering by randomly oriented spheroidal particles. Appl. Opt., 1980, v.19, p.962–974.

[141] Asano Sh., Yamamoto G. Light scattering by a spheroidal particle. Appl. Opt., 1975, v.14, p.29–49.

[142] Barber P.W. Resonance electromagnetic absorption by nonspherical dielectric objects. IEEE Trans. Microwave Theory Techn., 1977, v.MTT-25, p.373–381.

[143] Barber P.W. Scattering and absorption efficiencies for nonspherical dielectric objects - biological models. IEEE Trans. Biomed. Eng., 1978, v.BME-25, p.155–159.

[144] Barber P.W., Wang D.-S. Rayleigh-Gans-Debye applicability to scattering by nonspherical particles. Appl. Opt., 1978, v.17, p.797–803.

[145] Barber P.W., Wang D.-S. Rayleigh-Gans-Debye applicability to scattering by nonspherical particles: Corrigenda. Appl. Opt., 1979, v.18, p.962.

[146] Barber P.W., Wang D.-S., Long M.B. Scattering calculations using a microcomputer. Appl. Opt., 1981, v.20, p.1121–1123.

[147] Barber P.W., Yeh C. Scattering of electromagnetic waves by arbitrarily shaped dielectric bodies. Appl. Opt., 1975, v.14, p.2864–2872.

[148] Bates R.H.T., James J.R., Callett I.N.L., Miller R.F. An overview of point matching. Radio Elect. Eng., 1973, v.43, p.197–210.

[149] Beattie W.H., Both C. Table of dissymmetries and correction factors for use in light scattering. J. Phys. Chem., 1960, v.64, p.696–697.

[150] Beattie W.H., Tisinger R.M. Light-scattering functions and particle-scattering factors for ellipsoid of revolution. J. Opt. Soc. Am., 1969, v.59, p.818–821.

[151] Becher P. Dissymmetry of disks of negligible thickness. J. Phys. Chem., 1959, v.63, p.1213–1214.

[152] Beidl G., Bischof M., Glatz G., Porod G., Sacken J.Ch., Wawra H. Zur Roentgenkleinwinkelstreuung und Lichtstreuung verduennter kolloider Systeme. Streukurven regelmaessiger Koerper. Z. Electrochem., 1957, v.61, p.1311–1318.

[153] Bell B.W., Bickel W.S. Single fiber light scattering matrix: an experimental determination. Appl. Opt., 1981, v.20, p.3874–3879.

[154] Benincasa D.S., Barber P.W., Zhang J.Z., Hsieh W.F., Chang R.K. Spatial distribution of the internal and near-field intensities of large cylindrical and spherical scatterers. Appl. Opt., 1987, v.26, p.1348–1356.

[155] Bhagat D.M., Mehta R.V., Shah H.S. Extinction of light by oriented large particles. J. Colloid Interface Sci., 1981, v.81, p.14–20.

[156] Bickel W.S., Watkins A.J., Videen G. The light-scattering Mueller matrix elements for Rayleigh, Rayleigh-Gans, and Mie spheres. Am. J. Phys., 1987, v.55, p.559–561.

[157] Blum L. Light scattering from correlated polymer systems. Macromolec., 1975, v.8, p.457–464.

[158] Bohren C.F. Light scattering by an optically active sphere. Chem. Phys. Lett., 1974, v.29, p.458–462.

[159] Bohren C.F. Scattering of electromagnetic waves by an optically active shell. J. Chem. Phys., 1975, v.62, p.1566–1571.

[160] Bohren C.F. Scattering of electromagnetic waves by an optically active cylinder. J. Colloid Interface Sci., 1978, v.66, p.105–109.

[161] Bohren C.F., Huffman D.R. Absorption cross-section maxima and minima in IR absorption bands of small ionic ellipsoidal particles. Appl. Opt., 1981, v.20, p.959–962.

[162] Bohren C.F., Singham Sh.B. Backscattering by nonspherical particles: a review of methods and suggested new approaches. J. Geophys. Res., 1991, v.96, p.5269–5277.

[163] Born M. Quantenmechanik der Stossvorgaenge. Z. Phys., 1926, v.38, p.803–827.

[164] Bourrely C., Chiappetta P., Lemaire T. Electromagnetic scattering by large rotating particles in the eikonal formalism. Opt. Comm., 1989, v.70, p.173–176.

[165] Bourrely C., Chiappetta P., Lemaire T., Torresani B. Multidipole formulation of the coupled dipole method for electromagnetic scattering by an arbitrary particle. J. Opt. Soc. Am. A, 1992, v.9, p.1336–1340.

[166] Bourrely C., Chiappetta P., Torresani B. Light scattering by particles of arbitrary shape: a fractal approach. J. Opt. Soc. Am. A, 1986, v.3, p.250–255.

[167] Bourrely C., Torresani B., Chiappetta P. Scattering of an electromagnetic wave by an irregularly shaped object. Opt. Comm., 1986, v.58, p.365–368.

[168] Brunsting A., Mullaney P.F. Differential light scattering: a possible method of mammalian cell identification. J. Colloid Interface Sci., 1972, v.39, p.492–496.

[169] Brunsting A., Mullaney P.F. Light scattering from coated spheres: model for biological cells. J. Appl. Opt., 1972, v.11, p.675–680.

[170] Bryant F.D., Latimer P. Optical efficiencies of large particles of arbitrary shape and orientation. J. Colloid Interface Sci., 1969, v.30, p.291–304.

[171] Buitenhuis J. Scattering of light from cylindrical particles: coupled dipole method calculations and the range of validity of the Rayleigh-Gans-Debye approximation. J. Colloid Interface Sci., 1994, v.162, p.19–24.

[172] Burberg R. Die Beugung electromagnetischer Wellen am unendlich laengen Kreiszylinder. Z. Naturforsch., 1957, v.11a, p.800–806.

[173] Burberg R. Die Lichtstreuung and Kugel- und stuebchenfuermigen Teilchen von Wellenlaengen Groesse. Z. Naturforsch., 1956, v.11a, p.807–819.

[174] Bustamante C., Maestre M.F., Keller D., Tinoco I. Differential scattering (CIDS) of circularly polarized light by dense particles. J. Chem. Phys., 1984, v.80, p.4817–4823.

[175] Chen H.Y., Iskander M.F., Penner J.E. Light scattering and absorption by fractal agglomerates and coagulations of smoke aerosols. J. Mod. Opt., 1990, v.37, p.171–181.

[176] Chen T.W. Generalized eikonal approximation. Phys. Rev. C, 1984, v.30, p.585–592.

[177] Chen T.W. High energy light scattering in the generalized eikonal approximation. Appl. Opt., 1989, v.28, p.4096–4102.

[178] Chen T.W. Scattering of light by a stratified sphere in high energy approximation. Appl. Opt., 1987, v.26, p.4155–4158.

[179] Chen T.W., Smith W.S. Large-angle light scattering at large size parameters. Appl. Opt., 1992, v.31, p.6558–6560.

[180] Chiappetta P. A new model for scattering by irregular absorbing particles. Astron. and Astrophys., 1980, v.83, p.348–353.

[181] Chiappetta P. Multiple scattering approach to light scattering by arbitrarily shaped particles. J. Phys. A, 1980, v.13, p.2101–2108.

[182] Chiappetta P., Perrin J.M. Low-energy light scattering: a multiple-scattering description. Nuovo Cimento, 1987, v.9D, p.717–725.

[183] Chiappetta P., Torresani B. Electromagnetic scattering from a dielectric helix. Appl. Opt., 1988, v.27, p.4856–4860.

[184] Chylek P. Extinction cross sections of arbitrarily shaped randomly oriented nonspherical particles. J. Opt. Soc. Am., 1977, v.67, p.1348–1350.

[185] Chylek P., Grams G.W. Light scattering by irregular randomly oriented particles. Science, 1976, v.193, p.480–482.

[186] Chylek P., Klett J.D. Absorption and scattering of electromagnetic radiation by prismatic columns: anomalous diffraction approximation. J. Opt. Soc. Am. A, 1991, v.8, p.1713–1720.

[187] Chylek P., Klett J.D. Extinction cross sections of nonspherical particles in the anomalous diffraction approximation. J. Opt. Soc. Am. A, 1991, v.8, p.274–281.

[188] Cline M.P., Barber P.W., Chang R.K. Surface-enhanced electric intensities on transition- and noble-metal spheroids. J. Opt. Soc. Am. B, 1986, v.3, p.15–21.

[189] Cohen A., Acquista Ch. Light scattering by tilted cylinders: properties of partial wave coefficients. J. Opt. Soc. Am., 1982, v.72, p.531–534.

[190] Cohen A., Haracz R.D., Cohen L.D. Asymmetry factors for randomly oriented infinite cylinders. J. Appl. Phys., 1985, v.58, p.1135–12140.

[191] Cohen L.D., Haracz R.D., Cohen A., Acquista Ch. Scattering of light from arbitrarily oriented finite cylinders. Appl. Opt., 1983, v.22, p.742–748.

[192] Coletti A. Light scattering by nonspherical particles: a laboratory study. Aeros. Sci. Technol., 1984, v.3, p.39–52.

[193] Cooper D.E., Wang D.-S., Kerker M. Scattering of light by laser fusion targets with small defects. Appl. Opt., 1983, v.22, p.83–94.

[194] Cross D.A., Latimer P. General solution for the extinction and absorption efficiencies of arbitrarily oriented cylinders by an anomalous diffraction method. J. Opt. Soc. Am. A, 1970, v.60, p.904–907.

[195] Cruz L., Fonseca L.F., Gomez M. T-matrix approach for the calculation of local fields in the neighborhood of small clusters in the electrodynamic regime. Phys. Rev. B, 1989, v.40, p.7491–7500.

[196] Crusan O.R. Translational addition theorems for spherical vector wave functions. Quart. Appl. Math., 1962, v.20, p.33–40.

[197] Dautzenberg H., Hartmann M., Koch H. Zur Lichtstreuung an Polymerdispersionen. Teil 1. Theoretische Untersuchugen zur Auswertung von Streulichtkurven nach der Rayleigh-Debye-Naeherung und Mie-theorie. Acta Polym., 1979, v.30, p.290–296.

[198] Dawkins A.W.J., Nightingale N.R.V., South G.P., Sheppard R.J., Grant E.H. The role of water in microwave absorption by biological material with particular reference to microwave hazards. Phys. Med. Biol., 1979, v.24, p.1168–1176.

[199] Debye P. Der Lichtdruck auf Kugeln von beliebigem Material. Ann. Phys., 1909, v.30, p.57–136.

[200] Debye P. Molecular-weight determination by light scattering. J. Phys. Colloid Chem., 1947, v.51, p.18–31.

[201] Debye P. Zerstreuung von Roentgenstrahlen. Ann. Phys., 1915, v.46, p.809–823.

[202] Debye P., Anacker E.W. Micell shape from dissymmetry measurements. J. Phys. Colloid Chem., 1951, v.55, p.644–655.

[203] Dhont J.K.G. Light scattering from colloidal systems in the Rayleigh-Gans-Debye approximation - the effect of multiple scattering. Ph.D. thesis, Univ. Utrecht, 1985, p.1–107.

[204] Dhont J.K.G. Multiple Rayleigh-Gans-Debye scattering in colloidal systems -general theory and static light scattering. Physica A, 1983, v.120, p.238–262.

[205] Doremus R.H. Optical properties of small gold particles. J. Chem. Phys., 1964, v.40, p.2389–2396.

[206] Doty P., Steiner R.F. Light scattering and spectrophotometry of colloidal solutions. J. Chem. Phys., 1950, v.18, p.1211–1220.

[207] Doyle W.T. Absorption of light by colloids in alkali halide crystals. Phys. Rev., 1958, v.111, p.1067–1072.

[208] Doyle W.T. Optical properties of a suspension of metal spheres. Phys. Rev. B, 1989, v.39, p.9852–9858.

[209] Draine B.T. The discrete-dipole approximation and its application to interstellar graphite grains. Astrophys. J., 1988, v.333, p.848–872.

[210] Dungey C.E., Bohren C.F. Light scattering by nonspherical particles: a refinement to the coupled-dipole method. J. Opt. Soc. Am. A, 1991, v.8, p.81–87.

[211] Pecora R. (Ed.) Dynamic light scattering. Application of photon correlation spectroscopy. New York: Plenum Press, 1985.

[212] Elwenspoek M. Theory of light scattering from aspherical particles of arbitrary size. J. Opt. Soc. Am., 1982, v.72, p.747–755.

[213] Erma V.A. Exact solution for the scattering of electromagnetic waves from bodies of arbitrary shape. III. Obstacles with arbitrary electromagnetic properties. Phys. Rev., 1969, v.179, p.1238–1246.

[214] Evans B.T.N., Fournier G.R. Simple approximation to extinction efficiency valid over all size parameters. Appl. Opt., 1990, v.29, p.4666–4670.

[215] Evans L.B. Scattering of electromagnetic radiation by infinitely long, hollow, and coated cylinders. J. Opt. Soc. Am., 1964, v.54, p.1004–1007.

[216] Farone W.A. Generalization of Rayleigh-Gans scattering from radially inhomogeneous spheres. J. Opt. Soc. Am., 1965, v.55, p.737–738.

[217] Fournet G. Theoretical and experimental study of the diffusion of X-rays by dense aggregate of particles. Bull. Soc. Franc. Mineral. Cryst., 1951, v.74, p.34–172.

[218] Fournier G.R., Evans B.T.N. Approximation to extinction efficiency for randomly oriented spheroids. Appl. Opt., 1991, v.30, p.2042–2048.

[219] Fuller K.A. Scattering and absorption cross sections of compounded spheres. I. Theory for external aggregates. J. Opt. Soc. Am., 1995, v.11, p.3251–3260.

[220] Fuller K.A. Scattering and absorption cross sections of compounded spheres. II. Calculations for external aggregates. J. Opt. Soc. Am., 1995, v.12, p.881–892.

[221] Fuller K.A. Scattering and absorption cross sections of compounded spheres. III. Spheres containing arbitrarily located spherical inhomogeneities. J. Opt. Soc. Am., 1995, v.12, p.893–904.

[222] Fuller K.A., Kattawar G.W. Consummate solution to the problem of classical electromagnetic scattering by an ensemble of spheres. II. Clusters of arbitrary configuration. Opt. Lett., 1988, v.13, p.1063–1065.

[223] Gans R. Strahlungsdiagramme ultramikroskopisher Teilchen. Ann. Phys., 1925, v.76, p.29–38.

[224] Gans R. Ueber die Form ultramikroskopischer Goldteilchen. Ann. Phys., 1912, v.37, p.881–900.

[225] Gatecki A., Kryszewski M. Small-angle light scattering from hedrites, ovoids and spiral ovoids. J. Polym. Sci., 1974, v.12, p.455–469.

[226] Geidushek E.P., Holtzer A. Physical and chemical mechanisms in the injury of cells by ionizing radiations. in Adv. Biol. Med. Phys. Ed. by J.H. Lowrence and C.A. Tobias. New York: Academic Press, 1958, v.6, p.431.

[227] Geller P.E., Tsuei T.G., Barber P.W. Information content of the scattering matrix for spheroidal particles. Appl. Opt., 1985, v.24, p.2391–2396.

[228] Goedecke G.H., O'Brien S.G. Scattering by irregular inhomogeneous particles via the digitized Green's function algorithm. Appl. Opt., 1988, v.27, p.2431–2438.

[229] Gordon J.E. Simple method for approximating Mie scattering. J. Opt. Soc. Am., 1985, v.2, p.156–159.

[230] Gouesbet G., Grehan G. J. Opt., 1982, v.19, p.2486.

[231] Greenberg J.M. Absorption and emission of radiation by nonspherical particles. J. Colloid Interface Sci., 1972, v.39, p.513–519.

[232] Greenberg J.M. Scattering by nonspherical particles. J. Appl. Phys., 1960, v.31, p.82–84.

[233] Greenberg J.M., Libelo L.F., Lind A.C., Wang R.T. Scattering by nonspherical particles whose size is of the order of the wavelength. in Electromagnetic theory and antennas. Part I. Oxford: Pergamon Press, 1963, p.81–93.

[234] Greenberg J.M., Lind A.C., Wang R.T., Libelo L.F. Scattering by nonspherical systems. Princeton, N. J. Inst. Adv. Study, S. A., 1966, p.1–53.

[235] Greenberg J.M., Pedersen J.C. Microwave analog to the scattering of light by nonspherical particles. J. Appl. Phys., 1961, v.32, p.233–242.

[236] Grehan G., Maheu B., Gouesbet G. Scattering of laser beams by Mie scatter centers: numerical results using a localized approximation. Appl. Opt. 1986, v.25, p.3539–3548.

[237] Guinier A. La diffraction des rayons X aux tres petits angles: application a l'etude de phenomenes ultramicroscopiques. Ann. Phys. (Paris), 1939, v.12, p.161–237.

[238] Guinier A., Fournet G. Small-angle scattering of X-rays. New York: Wiley, 1955.

[239] Haracz R.D., Cohen L.D., Cohen A. Perturbation theory for scattering from dielectric spheroids and short cylinders. Appl. Opt., 1984, v.23, p.436–441.

[240] Haracz R.D., Cohen L.D., Cohen A. Scattering of linearly polarized light from randomly oriented cylinders and spheroids. J. Appl. Phys., 1985, v.58, p.3322–3327.

[241] Haracz R.D., Cohen L.D., Presley A.R.W., Cohen A. Scattering of linearly polarized microwave radiation from a dielectric target including the interaction between target elements. Appl. Opt., 1989, v.28, p.1338–1344.

[242] Harada Y., Asakura T., Murakami T. Determination of size and refractive index of single spherical particles on the basis of geometrical optics. Pure Appl. Opt., 1992, v.1, p.77–90.

[243] Harrrington R.F. Field computations by moments method. New York: McGraw-Hill, 1968.

[244] Hart R.W., Montroll E.W. On the scattering of plane waves by soft obstacles. I. Spherical obstacles. J. Appl. Phys., 1951, v.22, p.376–378.

[245] Hartmann M., Dautzenberg H., Koch H. Zur Lichtstreuung an Polymerdispersionen. Teil 2. Vergleichende Betrachtung der Intensitaetsfunktionen nach Rayleigh-Debye und Mie im Bereich kleiner Teilchen. Acta Polym., 1979, v.30, p.597–598.

[246] Hayashi N., Kawai H. Light-scattering patterns from random assembly of anisotropic rods of finite dimensions. Polym. J., 1972, v.3, p.140–148.

[247] Heller W. Theoretical and experimental investigation of the light scattering of colloidal spheres. in ICES electromagnetic scattering. Ed. by M. Kerker. New York: Pergamon Press, 1963, p.101–120.

[248] Heller W. Theoretical investigations on the light scattering of spheres XV. The wavelength exponents at small alpha values. J. Chem. Phys., 1964, v.40, p.2700–2705.

[249] Heller W., Bhatnagar H.L., Nakagaki M. Theoretical investigations on the light scattering of spheres. XIII. The "wavelength exponent" of differential turbidity spectra. J. Chem. Phys., 1962, v.36, p.1163–1170.

[250] Heller W., Nakagaki M. Light scattering of spheroids. I. Extension of the Rayleigh-Gans-Stevenson functions and their application for molecular weight and shape determinations at theta=90 deg. J. Chem. Phys., 1974, v.60, p.3889–3895.

[251] Heller W., Nakagaki M. Light scattering of spheroids. III. Depolarization of the scattered light. J. Chem. Phys., 1974, v.61, p.3619–3625.

[252] Heller W., Tibibian R.M., Nakagaki M., Papazian L. Flow light scattering. 1. Theoretical principles of the effect and apparatus for its measurement. J. Chem. Phys., 1970, v.52, p.4294–4305.

[253] Hemenger R.P. Birefringence of a medium of tenuous parallel cylinders. Appl. Opt., 1989, v.28, p.4030–4034.

[254] Holland A.C., Gagne G. The scattering of polarized light by polydisperse systems of irregular particles. Appl. Opt., 1970, v.9, p.1113–1121.

[255] Holoubek J. A simple representation of small-angle light scattering from an anisotropic sphere. J. Polym. Sci. (Part A-2), 1972, v.10, p.1461–1465.

[256] Holoubek J. Small-angle light scattering from an anisotropic sphere in the Rayleigh-Gans-Debye approximation: the Mueller matrix formalism. Appl. Opt., 1991, v.30, p.4987–4990.

[257] Holt A.R. The scattering of electromagnetic waves by single hydrometeors. Radio Sci., 1982, v.17, p.929–945.

[258] Holt A.R., Santoso B. The Fredholm integral method. II. The calculation of scattering amplitudes for potential scattering. J. Phys. B, 1973, v.6, p.2010–2017.

[259] Holt A.R., Shepherd J.W. Electromagnetic scattering by dielectric spheroids in the forward and backward directions. J. Phys. A, 1979, v.12, p.159–166.

[260] Holt A.R., Uzunoglu N.K., Evans B.G. An integral equation solution to the scattering of electromagnetic radiation by dielectric spheroids and ellipsoids. IEEE Trans. Anten. Propag., 1978, v.AP–26, p.706–712.

[261] Horn D., Benoit H. Etude experimentale de la lumiere diffusee par des betonnets anisotropes. J. Polym. Sci., 1953, v.10, p.29–37.

[262] Horn D., Benoit H., Oster G. . Etude de la lumiere diffusee par des solutions tres diluees de betonnets optiquement anisotropes. J. Chem. Phys., 1995, v.48, p.530–535.

[263] Hovenac E.A. Calculation of far-field scattering from nonspherical particles using a geometrical optics approach. Appl. Opt., 1991, v.30, p.4739–4746.

[264] Ikeda Y. Extension of the Rayleigh-Gans theory. in ISES electromagnetic scattering. Ed. by M. Kerker. New York: Pergamon Press, 1963, p.47–53.

[265] Iskander M.F., Chen H.Y., Penner J.E. Optical scattering and absorption by branched chains of aerosols. Appl. Opt., 1989, v.28, p.3083–3091.

[266] Iskander M.F., Lakhtakia A. Extension of the iterative EBCM to calculate scattering by low-loss or lossless elongated dielectric objects. Appl. Opt., 1984, v.23, p.948–953.

[267] Iskander M.F., Lakhtakia A., Durney C.H. A new iterative procedure to solve for scattering and absorption by dielectric objects. Proc. IEEE, 1982, v.70, p.1361–1362.

[268] Iskander M.F., Lakhtakia A., Durney C.H. A new procedure for improving the solution stability and extending the frequency range of the EBCM. IEEE Trans. Anten. Propag., 1983, v.AP–31, p.317–324.

[269] Iskander M.F., Olson S.C., Benner R.E., Yoshida D. Optical scattering by metallic and carbon aerosols of high aspect ratio. Appl. Opt., 1986, v.25, p.2514–2520.

[270] Jazbi B., Wickramasinghe N. Scattering by low-refractive index dielectric spheres and cylinders compared with rigorous calculations for hollow particles. Astrophys. Space Sci. 1991, v.179, p.303–311.

[271] Kato M., Eichinger B.E. Small angle X-ray scattering function for aggregates of globular proteins. Angewan. Macromol. Chem., 1976, v.51, p.61–68.

[272] Kattawar G.W., Hu Ch.R., Parkin M.E., Herb P. Mueller matrix calculations for dielectric cubes: comparison with experiments. Appl. Opt., 1987, v.26, p.4174–4180.

[273] Kerker M. The optics of colloidal silver: something old and something new. J. Colloid Interface Sci., 1985, v.105, p.297–313.

[274] Kerker M. The scattering light and other electromagnetic radiation. New York: Academic Press, 1969.

[275] Kerker M., Farone W.A. Applicability of Rayleigh-Gans scattering to spherical particles. J. Opt. Soc. Am., 1963, v.53, p.758–759.

[276] Kerker M., Kaufman L.H., Farone W.A. Scattering of electromagnetic waves from two concentric spheres when the outer shell has a variable refractive index. Numerical results. J. Opt. Soc. Am., 1966, v.56, p.1053–1056.

[277] Kerker M., Kratohvil J.P., Matijevic E. Light scattering functions for concentric spheres. Total scattering coefficients, m1 =2.1050, m2 =1.4821. J. Opt. Soc. Am., 1962, v.52, p.551–561.

[278] Kerker M., Matijevic E. Scattering of electromagnetic waves from concentric infinite cylinders. J. Opt. Soc. Am., 1961, v.51, p.506–508.

[279] Kerker M., Wang D.-S., Giles C.L. Electromagnetic scattering by magnetic spheres. J. Opt. Soc. Am., 1983, v.73, p.765–767.

[280] Khlebtsov N.G. Optics of fractal clusters in the anomalous diffraction approximation. J. Mod. Opt., 1993, v.40, p.2221–2235.

[281] Khlebtsov N.G. Orientational averaging of light scattering observables in the T-matrix approach. Appl. Opt., 1992, v.31, p.5359–5365.

[282] Khlebtsov N.G., Bogatyrev V.A., Dykman L.A., Melnikov A.G. Spectral extinction of colloidal gold and its biospecific conjugates. J. Colloid Interface Sci., 1996, v.180, p.436–445.

[283] Khlebtsov N.G., Bogatyrev V.A., Dykman L.A., Melnikov A.G. Spectral properties of colloidal gold and its conjugates with biospecific macromolecules. in Lasers in clinical chemistry and biotechnology. Ed. by S. Andersen-Engels and R. Pratesi. Proc. SPIE, 1996, v.2629.

[284] Khlebtsov N.G., Melnikov A.G., Bogatyrev V.A., Sirota A.I. The orientational optic effects in colloidal systems: approximate and exact approaches. in Colloid and molecular electro-optics. Ed. by B.R. Jennings and S.P. Stoylov. Bristol: IOP, 1992, p.13–20.

[285] Khlebtsov N.G., Melnikov A.G. Integral equation for light scattering problems: application to the orientationally induced birefringence of colloidal dispersions. J. Colloid Interface Sci., 1991, v.142, p.396–408.

[286] Khlebtsov N.G., Melnikov A.G. Structure factor and exponent of scattering by polydisperse fractal colloidal aggregates. J. Colloid Interface Sci., 1994, v.163, p.145–151.

[287] Khlebtsov N.G., Melnikov A.G., Bogatyrev V.A. The linear dichroism and birefringence of colloidal dispersions: approximate and exact approaches. J. Colloid Interface Sci., 1991, v.146, p.463–478.

[288] Khlebtsov N.G., Melnikov A.G., Shchyogolev S.Yu., Bogatyrev V.A., Sirota A.I. Anisotropic and spectral properties of biological scattering objects with the ordered particle orientation. in Quantification and localization using diffused photon in a highly scattering media. Ed. by B. Chance. Proc. SPIE, 1994, v.2082, p.33–42.

[289] Kiehl J.T., Ko M.W., Mugmai A., Chylek P. Perturbation approach to light scattering by non-spherical particles. in Light scattering by irregularly shaped particles. Ed. by D.W. Schuerman. New York: Plenum Press, 1980, p.141–152.

[290] Kirk J.T.O. A theoretical analysis of the contribution of agar cells to the attenuation of light within natural waters. III. Cylindrical and spheroidal cells. New Phytologist., 1976, v.77, p.341–358.

[291] Kleinman R.E., Roach G.F., van den Berg P.M. Convergent Born series for large refractive indices. J. Opt. Soc. Am., 1990, v.7, p.890–897.

[292] Klett J.D., Sutherland R.A. Approximate methods for modeling the scattering properties of nonspherical particles: evaluation of the Wentzel-Kramers-Brillouin method. Appl. Opt., 1992, v.31, p.373–386.

[293] Klose S. The scattering of light by dielectric particles. Astrophys. Space Sci., 1986, v.125, p.157–167.

[294] Koch A.L. Estimation of size of bacteria by low-angle light-scattering measurements: theory. J. Microb. Meth., 1986, v.5, p.221–235.

[295] Koch A.L. Some calculations on the turbidity of mitochondria and bacteria. Biochim. Biophus. Acta, 1961, v.51, p.429–441.

[296] Koch A.L. Theory of angular dependence of light scattering by bacteria and similar sized biological particles. J. Theor. Biol., 1968, v.18, p.133–156.

[297] Kotlarchuk M., Chen S.-H., Asano Sh. Accuracy of RGD approximation for computing light scattering properties of diffusing and motile bacteria. Appl. Opt., 1979, v.18, p.2470–2479.

[298] Kratky O., Porod G. Diffuse small-angle scattering of X-rays in colloid systems. J. Coll. Sci., 1949, v.4, p.35–70.

[299] Kratky O., Porod G. The dependence of the X-ray small-angle scattering on shape and size of colloidal particles in solution. Acta Phys. Austriaca, 1948, v.2, p.133–147.

[300] Kristensson G., Stroem S. Electromagnetic scattering from geophysical targets by means of the T-matrix approach: a review of some recent results. Radio Sci., 1982, v.17, p.903–912.

[301] Ksienski D.A., Senior T.B.A. Scattering by small thin dielectric particles. Appl. Opt., 1985, v.38, p.225–231.

[302] Ku J.C. Comparisons of coupled-dipole solutions and dipole refractive indices for light scattering and absorption by arbitrarily shaped or agglomerated particles. J. Opt. Soc. Am., 1993, v.10, p.336–342.

[303] Ku J.C., Felske J.D. The range of validity of the Rayleigh limit for computing Mie scattering and extinction efficiencies. J. Quant. Spectrosc. Rad. Transf., 1984, v.31, p.569–574.

[304] Ku J.C., Chim K.-H. A comparison of solutions for light scattering and absorption by agglomerated or arbitrarily-shaped particles. J. Quant. Spectrosc. Radiat. Transf., 1992, v.47, p.201–220.

[305] Lakhtakia A. Effective properties of a dilute random distributions of small, convex, perfectly conducting particles in a chiral fluid. Mod. Phys. Lett., 1991, v.5, p.1439–1445.

[306] Lakhtakia A. General theory of Maxwell-Garnett model for particulate composites with bi-isotropic host materials. Int. J. Electronics, 1992, v.73, p.1355–11362.

[307] Lakhtakia A. General theory of the Pursell-Pennypacker scattering approach and its extension to bianisotropic scatterers. Astrophys. J., 1992, v.394, p.494–499.

[308] Lakhtakia A. Polarizability dyadics of small bianisotropic spheres. J. Phys. France, 1990, v.51, p.2235–2242.

[309] Lakhtakia A. Polarizability dyadics of small chiral ellipsoids. Chem. Phys. Lett., 1990, v.174, p.583–586.

[310] Lakhtakia A. Recent contributions to classical electromagnetic theory of chiral media: what next? Speculat. Sci. Techn., 1990, v.14, p.2–17.

[311] Lakhtakia A. Scattering by an infinitely-long bianisotropic cylinder with electrically small, convex cross-section. Opt. Comm., 1991, v.80, p.303–306.

[312] Lakhtakia A. Size-dependent Maxwell-Garnett formula from an integral equation formalism. Optik., 1992, v.91, p.134–137.

[313] Lakhtakia A. Strong and weak forms of the method of moments and the coupled dipole method for scattering of time-harmonic electromagnetic fields. Int. J. Mod. Phys., 1992, v.3, p.583–603.

[314] Lakhtakia A. The extended boundary condition method for scattering by a chiral scatterer in a chiral medium: formulation and analysis. Optik., 1991, v.86, p.155–161.

[315] Lakhtakia A. Toward classifying elementary microstructures in thin films by their scattering responses. Int. J. Infrared Millim. Waves, 1992, v.13, p.869–886.

[316] Lakhtakia A., Iskander M.F. Theoretical and experimental evaluation of power absorption in elongated biological objects at and beyond resonance. IEEE Trans. Electromag. Compat., 1983, v.EMC–25, p.448–453.

[317] Lakhtakia A., Mulholland G.W. On two numerical techniques for light scattering by dielectric agglomerated structures. J. Res. Natl. Inst. Stand. Technol., 1993, v.98, p.699–716.

[318] Lakhtakia A., Varadan V.K., Varadan V.V. Iterative extended boundary condition method for scattering by objects of high aspect ratios. J. Acoust. Soc. Am., 1984, v.76, p.906–912.

[319] Lakhtakia A., Varadan V.K., Varadan V.V. Scattering and absorption characteristics of lossy dielectric, chiral, nonspherical objects. Appl. Opt., 1985, v.24, p.4146–4154.

[320] Latimer P. Light scattering by a homogeneous sphere with radial projections. Appl. Opt., 1984, v.23, p.442–447.

[321] Latimer P. Light scattering by a structured particle: the homogeneous sphere with holes. Appl. Opt., 1984, v.23, p.1844–1847.

[322] Latimer P. Light scattering by ellipsoids. J. Colloid Sci., 1975, v.53, p.102–109.

[323] Latimer P. Predicted scattering by spheroids: comparison of approximate and exact methods. Photochem. Photobiol., 1980, v.19, p.3039–3041.

[324] Latimer P., Barber P.W. Scattering by ellipsoids of revolution. A comparison of theoretical methods. J. Colloid Interface Sci., 1978, v.63, p.310–316.

[325] Levine S., Kerker M. The scattering of electromagnetic waves from two concentric spheres, when the outer sphere has a variable index of refraction. in ICES electromagnetic scattering. Ed. by M.Kerker. New York: Pergamon Press, 1963, p.37–46.

[326] Lind A.C. Electromagnetic scattering by obliquely oriented cylinders. J. Appl. Phys., 1966, v.37, p.3195–3203.

[327] Lind A.C., Greenberg J.M. Electromagnetic scattering by obliquely oriented cylinders. Princeton, N. J. Inst. Adv. Study, S. A., 1966.

[328] Liou K.N., Cai Q., Barber P.W., Hill S.C. Scattering phase matrix comparison for randomly hexagonal cylinders and spheroids. Appl. Opt., 1983, v.22, p.1684–1687.

[329] Lock J.A. Improved Gaussian beam-scattering algorithm. Appl. Opt., 1995, v.34, p.559–570.

[330] Love A.E.H. The scattering of electric waves by a dielectric sphere. Proc. London Math. Soc., 1899, v.30, p.308–321.

[331] Ma Y., Varadan V.V., Varadan V.K. Scattered intensity of a wave propagating in a discrete random medium. Appl. Opt., 1988, v.27, p.2469–2477.

[332] Macke A., Mishchenko M.I., Muinonen K., Carlson B.E. Scattering of light by large nonspherical particles: ray-tracing approximation versus T-matrix method. Opt. Lett., 1995, v.20, p.1934–1936.

[333] Maheu B., Grehan G., Gouesbet G. Generalized Lorenz-Mie theory: first exact values and comparisons with the localized approximation. Appl. Opt., 1987, v.26, p.23–25.

[334] Majolino D., Mallamace F., Migliardo P., Micali N., Vasi C. Elastic and quasielastic light-scattering studies of the aggregation phenomena in water solutions of polystyrene particles. Phys. Rev. A, 1989, v.40, p.4665–4674.

[335] Malmon A.G. Small-angle X-ray scattering functions for ellipsoid of revolution and right circular cylinders. Acta Cryst., 1957, v.10, p.639–642.

[336] McClain W.M., Ghoul W.A. Elastic light scattering by randomly oriented macromolecules: computation of the complete set of observables. J. Chem. Phys., 1986, v.84, p.6609–6622.

[337] Meeten G.H. An anomalous diffraction theory of linear birefringence and dichroism in colloidal dispersion. J. Colloid Interface Sci., 1982, v.87, p.407–415.

[338] Meeten G.H. Induced birefringence in colloidal dispersions. J. Chem. Soc. Faraday Trans. Part 2, 1979, v.75, p.1406–1415.

[339] Meeten G.H. Small-angle light scattering by spherulites in the anomalous diffraction approximation. Opt. Acta, 1982, v.29, p.759–770.

[340] Meeten G.H. The birefringence of colloidal dispersions in the Rayleigh and anomalous diffraction approximations. J. Colloid Interface Sci., 1980, v.73, p.38–41.

[341] Meeten G.H. The intrinsic optical anisotropy of colloidal particles in the anomalous diffraction approximation. J. Colloid Interface Sci., 1980, v.74, p.181–185.

[342] Mie G. Beitraege zur Optik trueber Medien, speziell kolloidaler Metalloesungen. Ann. Phys., 1908, v.25, p.377–445.

[343] Mikulski J.J., Murphy E.L. The computation of electromagnetic scattering from concentric spherical structures. IEEE Trans. Anten. Propag., 1963, v.AP–11, p.169–177.

[344] Mishchenko M.I. Extinction and polarization of transmitted light by partially aligned nonspherical grains. Astrophys. J., 1991, v.367, p.561–574.

[345] Mishchenko M.I. Extinction of light by randomly-oriented non-spherical grains. Asptrophys. Space Sci., 1990, v.164, p.1–13.

[346] Mishchenko M.I. Infrared absorption by shape distributions of NH3 ice particles: an application to the Jovian atmosphere. Earth, Moon, Planets, 1991, v.53, p.149–156.

[347] Mishchenko M.I. Light scattering by nonspherical ice grains: an application to noctilucent cloud particles. Earth, Moon, Planets, 1992, v.57, p.203–211.

[348] Mishchenko M.I. Light scattering by randomly oriented axially symmetric particles. J. Opt. Soc. Am. A, 1991, v.8, p.871–882.

[349] Mishchenko M.I. Light scattering by size-shape distributions of randomly oriented axially symmetric particles of a size comparable to a wavelength. Appl. Opt., 1993, v.32, p.4652–4666.

[350] Mishchenko M.I. Reflection of polarized light by plane-parallel slabs containing randomly-oriented, nonspherical particles. J. Quant. Spectrosc. Rad. Transf., 1991, v.46, p.171–181.

[351] Mishchenko M.I., Dlugach J.M., Yanovitskij E.G. Multiple light scattering by polydispersions of randomly distributed, perfectly-aligned, infinite Mie cylinders illuminated perpendicularly to their axes. J. Quant. Spectrosc. Rad. Transf., 1992, v.47, p.401–410.

[352] Mishchenko M.I., Hovenier J.W. Depolarization of light backscattered by randomly oriented nonspherical particles. Opt. Lett., 1995, v.20, p.1356–1358.

[353] Mishchenko M.I., Mackowski D.W. Electromagnetic scattering by randomly oriented bispheres: comparison of theory and experiment and benchmark calculations. J. Quant. Spectrosc. Rad. Transf., 1996, v.55, p.683–694.

[354] Mishchenko M.I., Mackowski D.W. Light scattering by randomly oriented bispheres. Opt. Lett., 1994, v.19, p.1604–1606.

[355] Mishchenko M.I., Mackowski D.W., Travis L.D. Scattering of light by bispheres with touching and separated components. Appl. Opt., 1995, v.34, p.4589–4599.

[356] Mishchenko M.I., Travis L.D. Light scattering by polydispersions of randomly oriented spheroids with sizes comparable to wavelengths of observation. Appl. Opt., 1994, v.33, p.7206–7225.

[357] Mishchenko M.I., Travis L.D. Light scattering by size/shape distributions of nonspherical particles of size comparable to a wavelength. in Atmospheric propagation and remote sensing, II. Ed. by A.Kohnle and W.B. Miller. Proc. SPIE, 1993, v.1968, p.118–129.

[358] Mishchenko M.I., Travis L.D. Light scattering by polydisperse rotationally symmetric nonspherical particles: linear polarization. J. Quant. Spectrosc. Rad. Transf., 1994, v.51, p.759–778.

[359] Mishchenko M.I., Travis L.D. T-matrix computations of light scattering by large spheroidal particles. Opt. Comm., 1994, v.109, p.16–21.

[360] Mishchenko M.I., Travis L.D., Lacis A.A., Carlson B.E. . Satellite remote sensing of nonspherical tropospheric aerosols. in Atmospheric sensing and modeling. Ed. by R. Santer. Proc. SPIE, 1994, v.2311, p.150–161.

[361] Mishchenko M.I., Travis L.D., Mackowski D.W. T-matrix computations of light scattering by large nonspherical particles: recent advances. in Passive infrared remote sensing of clouds and the atmosphere. Ed. by D.K. Lynch. Proc. SPIE, 1994, v.2309, p.72–83.

[362] Mishchenko M.I., Travis L.D., Mackowski D.W. T-matrix computations of light scattering by nonspherical particles: a review. J. Quant. Spectrosc. Radiat. Transf., 1996, v.55, p.535–575.

[363] Mittelbach P. Einige spezielle Bestimmungsmethoden von Form und Polydispersitaet kolloider Teilchen in verduter Loesung mittels Roentgenkleinwinkelstreuung. Kolloid-Z. und Z. Polym., 1965, v.206, p.152–159.

[364] Mittelbach P. Zur Roentgenkleinwinkelstreuung verdunter kolloider Systeme. VIII. Diskussion des Streuverhaltens regelmaessiger Koerper und Methoden zur Bestimmung von Groesse und Form kolloider Teilchen. Acta Phys. Austriaca., 1964, v.19, p.53–102.

[365] Mittelbach P., Porod G. X-ray low-angle scattering by dilute colloidal systems. VI.The calculation of scattering curves of elliptical and hollow cylinders. Acta Phys. Austriaca., 1961, v.14, p.409–439.

[366] Mittelbach P., Porod G. X-ray small-angle scattering of dilute colloidal systems. VII.Computations for scattering curves of triaxial ellipsoids. Acta Phys. Austriaca., 1962, v.15, p.122–147.

[367] Mittelbach P., Porod G. Zur Rtsntgenkleinwinkelstreuung und Kohdrenzldnge eines kolloiden Systems: Kennzahlen zur Ermittlung von Teilchenform und Polydispersitdtsgrad. Kolloid-Z. und Z. Polym., 1965, v.202, p.40–49.

[368] Moeglich F. Beugungserscheinungen an Korpen von ellipsoidischer Gestalt. Ann. Phys., 1927, v.83, p.609–735.

[369] Molcho Y., Reynolds L.O. On the Rayleigh-Gans interference factor for particles with rotational and fore-aft symmetries. J. Colloid Interface Sci., 1976, v.54, p.149–150.

[370] Monroll E.W., Hart R.W. Scattering of plane waves by soft obstacles. II. Scattering by cylinders, spheroids and disks. J. Appl. Phys., 1951, v.22, p.1278–1289.

[371] Monzon J.C. Three-dimensional field expansion in the most general rotationally symmetric anisotropic material: application to scattering by a sphere. IEEE Trans. Anten. Propag., 1989, v.37, p.728–735.

[372] Morrison J.A., Chu T.S. Perturbation calculations of rain-induced differential attenuation and differential phase shift at microwave frequencies. Bell. Syst. Tech. J., 1973, v.52, p.1907–1913.

[373] Morrison J.A., Cross M.-J., Chu T.S. Rain-induced differential attenuation and differential phase shift at microwave frequencies. Bell Syst. Tech. J., 1973, v.52, p.599–604.

[374] Morrison J.A., Cross M.-J., Chu T.S. Scattering of a plane electromagnetic wave by axisymmetric raindrops. Bell Syst. Tech. J., 1974, v.53, p.955–1019.

[375] Murakami Y., Nayashi N., Hashimoto T., Kawai H. Light scattering patterns from random assembly of anisotropis rod-like structures with their principal optic axes oriented in cylindrical symmetry with respect to their own rod axes. Polym J., 1973, v.4, p.452–459.

[376] Nakagaki M., Heller W. Flow light scattering. II.Theoretical results for flow oriented, homogeneous, and isotropic spheroids. J. Chem. Phys., 1976, v.64, p.3797–3803.

[377] Nakagaki M., Heller W. Light scattering of spheroids. II. Angular dispersion and dissymmetry of light scattering. J. Chem. Phys., 1974, v.61, p.3297–3303.

[378] Napper D.H. Light scattering by polyhedral particles in the Rayleigh-Gans domain. Kolloid-Z. und Z. Polym., 1968, v.223, p.141.

[379] Napper D.H., Ottewill R.H. Light scattering by cubical particles in the Rayleigh-Gans domain. Kolloid-Z. und Z. Polym., 1963, v.192, p.114–117.

[380] Nelson A., Eyges L. Electromagnetic scattering from dielectric rods of arbitrary cross section. J. Opt. Soc. Am., 1976, v.66, p.254–259.

[381] Neugebauer Th. Berechnung der Lichtzerstreuung von Fadenkettenloesungen. Ann. Phys., 1943, v.42, p.510–533.

[382] Oguchi T. Attenuation and phase rotation of radio waves due to rain: calculation at 19.3 and 34.8 GHz. Radio Sci., 1973, v.8, p.31–38.

[383] Oguchi T. Attenuation of electromagnetic wave due to rain with distorted raindrops. J. Radio Res. Labs. (Tokio), 1960, v.7, p.467–485.

[384] Oguchi T. Scattering from hydrometeors: a survey. Radio Sci., 1981, v.16, p.691–730.

[385] Oguchi T. Scattering properties of oblate raindrops and cross polarization of radio waves due to rain: calculation at 19.3 and 38.4 GHz. J. Radio Res. Labs. (Tokio), 1973, v.20, p.79–118.

[386] Onuki A., Doi M. Flow birefringence and dichroism of polymers. I. General theory and application to the dilute case. J. Chem. Phys., 1986, v.85, p.1190–1197.

[387] Papadakis S.N., Uzunoglu N.K., Capsalis C.N. . Scattering of a plane wave by a general anisotropic dielectric ellipsoid. J. Opt. Soc. Am. A, 1990, v.7, p.991–997.

[388] Paramonov L.E. Light scattering by randomly oriented particles into solid angles. J. Opt. Soc. Am. A, 1994, v.11, p.1360–1369.

[389] Patterson A.L. The diffraction of X-rays by small crystallite particles. Phys. Rev., 1939, v.56, p.972–977.

[390] Perelman A.Y. An application of Mie's series to soft particles. Pageoph., 1978, v.116, p.1078–1088.

[391] Perelman A.Y. On the scattering from soft particles. J. Colloid Interface Sci., 1978, v.63, p.593–596.

[392] Perrin J.M., Chiappetta P. Light scattering by large particles. I. A new theoretical description in the eikonal picture. Opt. Acta, 1985, v.32, p.907–921.

[393] Perrin J.M., Lamy Ph.L. Light scattering by large particles II. A vectorial description in the eikonal picture. Opt. Acta, 1986, v.33, p.1001–1022.

[394] Perry R.J., Hunt A.J., Huffman D.R. Experimental determinations of Mueller scattering matrices for nonspherical particles. Appl. Opt., 1978, v.17, p.2700–2710.

[395] Peterson B., Stroem S. T matrix for electromagnetic scattering from an arbitrary number of scatterers and representations of E(3). Phys. Rev. D, 1973, v.8, p.3661–3678.

[396] Peterson B., Stroem S. T-matrix formulation of electromagnetic scattering from multilayered scatterers. Phys. Rev. D, 1974, v.10, p.2670–2684.

[397] Petres J.J., Dezelic G. Light scattering by large ellipsoidal particles. I. Rayleigh-Debye approach. J. Colloid Interface Sci., 1975, v.50, p.296–306.

[398] Philipse A.P., Smits C., Vrij A.A. A light scattering contrast variation study on nonaqueous suspensions of coated silica spheres. J. Colloid Interface Sci., 1989, v.129, p.335–352.

[399] Picot C., Weill G., Benoit H. Light scattering by anisotropic discs. Application to polymer single crystals. J. Colloid Interface Sci., 1968, v.27, p.360–376.

[400] Platzman P.M., Ozaki H.T. Scattering of electromagnetic waves from an infinitely long magnetized cylindrical plasma. J. Appl. Phil., 1960, v.31, p.1597–1601.

[401] Poggio A.J., Miller E.K. Integral equation solutions of there-dimensional scattering problems. in Computer Techniques for Electromagnetics. Oxford, 1973, p.159–264.

[402] Porod G. The dependence of the X-ray small-angle scattering on shape and size of colloidal particles in solution. Acta Phys. Austriaca, 1948, v.2, p.252–292.

[403] Prud'homme R.E., Stein R.S. Light scattering by assemblies of spherulites. J. Polym. Sci. Polym. Symp., 1973, v.11, p.1357–1374.

[404] Purcell E.M., Pennypacker C.R. Scattering and absorption of light by non-spherical dielectric grains. Astrophys. J., 1973, v.186, p.705–714.

[405] Ramm A.G. Wave scattering by small bodies. Repor. Math. Phys., 1985, v.21, p.69–77.

[406] Ravey J.-C. Diffusion de la lumiere dans une direction quelconque par des particules anisotropes orientees par un champ electrique. I. Expressions generales. Eur. Polym. J., 1972, v.8, p.937–973.

[407] Ravey J.-C. Diffusion de la lumiere par des suspensions de particules anisotropes. II. Eur. Polym. J., 1973, v.9, p.47–56.

[408] Ravey J.-C. Diffusion de la lumiere par des suspensions de particules anisotropes. III. Eur. Polym. J., 1973, v.9, p.57–69.

[409] Ravey J.-C. Light scattering and birefringence of flow-oriented spheroids. Comparison of exact and R.G.D approximate theories. J. Colloid Interface Sci., 1977, v.60, p.389–401.

[410] Ravey J.-C. Light scattering in the third-order and R.G.D. approximation. The form anisotropy in electro-optics. J. Colloid Interface Sci., 1976, v.56, p.540–556.

[411] Ravey J.-C. Light scattering, turbidity, and conservative dichroism of suspensions of anisotropic particles in an electrical field. J. Polym. Sci. Polym. Symp. 42, 1973, v.3, p.1131–1145.

[412] Ravey J.-C. The first extrema in the radiation pattern of the light scattering by micrometer-sized spheres and spheroids. J. Colloid Interface Sci., 1985, v.105, p.435–446.

[413] Ravey J.-C., Mazeron P.J. Light scattering by large spheroids in the physical optics approximation: numerical comparison with other approximate and exact results. J. Opt. (Paris), 1983, v.14, p.29–41.

[414] Ravey J.-C., Mazeron P.J. Light scattering in the physical optics approximation: application to large spheroids. J. Opt. (Paris), 1982, v.13, p.273–282.

[415] Ravey J.-C., Mazeron P.J. Particle size from optical anisotropy effects in scattered light. Polymer., 1983, v.84, p.991–994.

[416] Rayleigh D.W. On the diffraction of light by spheres of small refractive index. Proc. R. Soc. London Ser. A, 1914, v.90, p.219–225.

[417] Rayleigh D.W. On the dispersal of light by a dielectric cylinder. Phil. Mag., 1918, v.36, p.365–376.

[418] Rayleigh D.W. On the electromagnetic theory of light. Phil. Mag. S.5, 1881, v.12, p.81–101.

[419] Rayleigh D.W. On the incidence of aerial and electric waves upon small obstacles in the from of ellipsoids or elliptic cylinders, and on the passage of electric waves through a circular aperture in a conducting screen. Phil. Mag. S.5, 1897, v.44, p.28–52.

[420] Rayleigh D.W. On the propagation of waves through a stratified medium, with special reference to the question of reflection. Proc. R. Soc. London Ser. A, 1912, v.86, p.207–223.

[421] Rayleigh D.W. On the scattering of light by small particles. Phil. Mag. S.5, 1871, v.41, p.447–454.

[422] Rayleigh D.W. The incidence of light upon a transparent sphere of dimensions comparable with the wavelength. Proc. R. Soc. London, 1910, v.84, p.25–46.

[423] Rhodes M.B., Stein R.S. Scattering of light from assemblies of oriented rods. J. Polym. Sci. (Part A-2), 1969, v.7, p.1539–1558.

[424] Richmond J.H. Scattering by a dielectric cylinder of arbitrary cross section shape. IEEE Trans. Anten. Propag., 1965, v.AP-13, p.334–341.

[425] Rockwitz J.-D. Scattering properties of horizontally oriented ice crystal columns in cirrus clouds. Part 1. Appl. Opt., 1989, v.28, p.4103–4110.

[426] Roess L.C., Shull C.G. X-ray scattering at small angles by finely-divided solids. II.Exact theory for random distribution of spheroidal particles. J. Appl. Phys., 1947, v.18, p.308–313.

[427] Roessler D.M., Wang D.-S., Kerker M. Optical absorption by randomly oriented carbon spheroids. Appl. Opt., 1983, v.22, p.3648–3651.

[428] Saito N., Ikeda Y. The light scattering by nonspherical particles in solutions. J. Phys. Soc. Japan, 1951, v.6, p.305–308.

[429] Samuels R.J. Small-angle light scattering from optically anisotropic spheres and discs. Theory and experimental verification. J. Polym. Sci. (Part A-2), 1971, v.9, p.2165–2246.

[430] Schuerman D.W., Wang R.T., Gustafson B.A.S., Schaefer R.W. Systematic studies of light scattering. 1: Particle shape. Appl. Opt., 1981, v.20, p.4039–4050.

[431] Senior T.B.A. Effect of particle shape on low frequency absorption. Appl. Opt., 1980, v.19, p.2483–2485.

[432] Senior T.B.A. Scalar diffraction by a prolate spheroid at low frequencies. Can. J. Phys., 1960, v.38, p.1632–1641.

[433] Senior T.B.A. The scattering of an electromagnetic wave by a spheroid. Can. J. Phys., 1966, v.44, p.1353–1359.

[434] Senior T.B.A., Weil H. Electromagnetic scattering and absorption by thin walled dielectric cylinders with application to ice crystals. Appl. Opt., 1977, v.16, p.2979–2985.

[435] Shafai L. Scattering by spherically symmetrical objects. Can. J. Phys., 1972, v.50, p.749–753.

[436] Shanker B., Lakhtakia A. Extended Maxwell Garnett formalism for composite adhesives for microwave-assisted adhesion of polymer surfaces. J. Composite Mater., 1993, v.27, p.1203–1213.

[437] Sharma S.K. Approximate formulae for the scattering of light by oriented, infinitely long, homogeneous, soft circular cylinders. J. Mod. Opt., 1989, v.36, p.399–404.

[438] Sharma S.K., Powers S.R., Somerford D.J. Investigation of domains of validity of approximation methods in forward light scattering from long cylinders. Opt. Acta, 1981, v.28, p.1439–1446.

[439] Sharma S.K., Roy T.K., Somerford D.J. Approximate formulae for the scattering of radiation from infinitely long homogeneous right-circular soft cylinders. J. Mod. Opt., 1988, v.35, p.1213–1224.

[440] Shi Y., McClain W.M. Closed-form Mueller scattering matrix for a randomly ensemble of long, thin cylinders. J. Chem. Phys., 1993, v.98, p.1695–1711.

[441] Shiff L.I. Scattering of waves and particles by inhomogeneous regions. J. Opt. Soc. Am., 1962, v.52, p.140–146.

[442] Shiff L.I. Approximation method for high-energy potential scattering. Phys. Rev., 1956, v.103, p.443–453.

[443] Shifrin K.S., Mikulinski I.A. Ensemble approach to the problem of light scattering by a system of tenuous particles. Appl. Opt., 1987, v.26, p.3012–3017.

[444] Shimizu K. Modification of the Rayleigh-Debye approximation. J. Opt. Soc. Am., 1983, v.73, p.504–507.

[445] Shmidt P.W. The small-angle X-ray scattering from polydisperse solution of ellipsoidal particles. Acta Cryst., 1958, v.11, p.674–676.

[446] Shmidt P.W., Hight R.Jr. Calculation of the intensity of small-angle X-ray scattering at relatively large scattering angles. J. Appl. Phys., 1959, v.30, p.866–871.

[447] Shull C.G., Roess L.C. X-ray scattering at small angles by finely-divided solids. I. General approximate theory and applications. J. Appl. Phys., 1947, v.18, p.295–307.

[448] Singham M.K., Singham Sh.B., Salzman G.C. The scattering matrix for randomly oriented particles. J. Chem. Phys., 1986, v.85, p.3807–3815.

[449] Singham Sh.B. Form and intrinsic optical activity in light scattering by chiral particles. J. Chem. Phys., 1987, v.87, p.1873–1881.

[450] Singham Sh.B. Intrinsic optical activity in light scattering from an arbitrary particle. Chem. Phys. Lett., 1986, v.130, p.139–144.

[451] Singham Sh.B., Bohren C.F. Hybrid method in light scattering by an arbitrary particle. Appl. Opt., 1989, v.28, p.517–522.

[452] Singham Sh.B., Bohren C.F. Light scattering by an arbitrary particle: a physical reformulation of the coupled dipole method. Opt. Lett., 1987, v.12, p.10–12.

[453] Singham Sh.B., Bohren C.F. Light scattering by an arbitrary particles: the scattering-order formulation of the coupled-dipole method. J. Opt. Soc. Am. A, 1988, v.5, p.1867–1872.

[454] Singham Sh.B., Patterson C.W., Salzman G.C. Polarizabilities for light scattering from chiral particles. J. Chem. Phys., 1986, v.85, p.763–770.

[455] Singham Sh.B., Salzman G.C. Evaluation of the scattering matrix of an arbitrary particle using the coupled dipole approximation. J. Chem. Phys., 1986, v.84, p.2658–2667.

[456] Stein R.S., Erhardt P., van Aartsen J.J., Clough S., Rhodes M.B. Theory of light scattering from oriented and fiber structures. J. Polym. Sci. (Part C), 1966, p.1–35.

[457] Stein R.S., Rhodes M.B. Photographic light scattering by polyethylene films. J. Appl. Phys., 1960, v.31, p.1873–1884.

[458] Stevenson A.F. Electromagnetic scattering by an ellipsoid in the third approximation. J. Appl. Phys., 1953, v.24, p.1143–1151.

[459] Stevenson A.F. Light scattering by spheroidal particles oriented by streaming. J. Chem. Phys., 1968, v.49, p.4545–4550.

[460] Stevenson A.F. Solution of electromagnetic scattering problems as power series in the ratio (dimension of scattering)/wavelength. J. Appl. Phys., 1953, v.24, p.1134–1142.

[461] Stoimenova M., Stoylov S.P. Orientational optic effects from above Rayleigh particles. J. Colloid Interface Sci., 1980, v.76, p.502–514.

[462] Stoylov S.P., Stoimenova M. Anisotropy of the optical polarizability in the Rayleigh-Debye-Gans approximation. J. Colloid Interface Sci., 1977, v.59, p.179–180.

[463] Stroem S. On the integral equations for electromagnetic scattering. Am. J. Phys., 1975, v.43, p.1060–1069.

[464] Stroem S. T-matrix for electromagnetic scattering from an arbitrary number of scatterers with continuously varying electromagnetic properties. Phys. Rev. D, 1974, v.10, p.2685–2690.

[465] Tagami Y., Pecora R. Light scattering from polydisperse rods and Gaussian coils. I. Integrated intensities. J. Chem. Phys., 1969, v.51, p.3293–3298.

[466] Tian D., McClain W.M. Nondipole light scattering by partially oriented ensembles 1. Numerical calculations and symmetries. J. Chem. Phys., 1989, v.90, p.4783–4794.

[467] Tsai C.-T., Massoudi H., Durney C.H., Iskander M.F. A procedure for calculating fields inside arbitrarily shaped, inhomogeneous dielectric bodies using linear basis functions with the moment method. IEEE Trans. Microwave Theory Techn., 1986, v.MTT-34, p.1131–1139.

[468] Tsang L. Scattering of electromagnetic waves from a half space of nonspherical particles. Radio Sci., 1984, v.19, p.1450–1460.

[469] Tsang L., Kong J.A. Effective propagation constants for coherent electromagnetic wave propagation in media embedded with dielectric scatters. J. Appl. Phys., 1982, v.53, p.7162–7173.

[470] Tsang L., Kong J.A. Multiple scattering of electromagnetic waves by random distributions of discrete scatterers with coherent potential and quantum mechanical formalism. J. Appl. Phys., 1980, v.51, p.3465–3485.

[471] Tsang L., Kong J.A. Scattering of electromagnetic waves from a half space of densely distributed dielectric scatterers. Radio Sci., 1983, v.18, p.1260–1272.

[472] Tsang L., Kong J.A., Shin R.T. Radiative transfer theory for active remote sensing of a layer of nonspherical particles. Radio Sci., 1984, v.19, p.629–642.

[473] Tsang L., Kubacsi M.C., Kong J.A. Radiative transfer theory for active remote sensing of a layer of small ellipsoidal scatterers. Radio Sci., 1981, v.16, p.321–329.

[474] Turner L. Rayleigh-Gans-Born light scattering by ensembles randomly oriented anisotropic particles. Appl. Opt. 1976, v.15, p.1085–1090.

[475] Twersky V. Absorption and multiple scattering by biological suspensions. J. Opt. Soc. Am., 1970, v.60, p.1084–1093.

[476] Uzunoglu N.K., Alexopoulos N.G., Fikioris J.G. Scattering from thin and finite dielectric fibers. J. Opt. Soc. Am., 1978, v.68, p.194–197.

[477] Uzunoglu N.K., Evans B.G., Holt A.R. Evaluation of the scattering of an electromagnetic wave from precipitation particles by the use of Fredholm integral equations. Electron. Lett., 1976, v.12, p.312–313.

[478] Uzunoglu N.K., Holt A.R. The scattering of electromagnetic radiation from dielectric scattering. J. Phys. A, 1977, v.10, p.413–424.

[479] Van Aartsen J.J. Light scattering from a random collection of cylinder-symmetrical particles. Eur. Polym. J., 1970, v.6, p.1095–1104.

[480] Varadan V.K., Bringi V.N., Varadan V.V. Coherent electromagnetic wave propagation through randomly distributed dielectric scatterers. Phys. Rev. D, 1979, v.19, p.2480–2489.

[481] Varadan V.K., Bringi V.N., Varadan V.V. Multiple scattering theory for waves in discrete random media and comparison with experiments. Radio Sci., 1983, v.18, p.321–327.

[482] Varadan V.K., Ma Y., Varadan V.V. Coherent electromagnetic wave propagation through randomly distributed and oriented pair-correlated dielectric scatterers. Radio Sci., 1984, v.19, p.1445–1449.

[483] Varadan V.V., Lakhtakia A., Varadan V.K. Comments on recent criticism of the T-matrix method. J. Acoust. Soc. Am., 1988, v.84, p.2280–2284.

[484] Varadan V.V., Lakhtakia A., Varadan V.K. Scattering by three-dimensional anisotropic scatterers. IEEE Trans. Anten Propag., 1989, v.37, p.800–802.

[485] Varadan V.V., Ma Y., Varadan V.K. Propagator model including multipole fields for discrete random media. J. Opt. Soc. Am. A, 1985, v.2, p.2195–2201.

[486] Varadan V.V., Varadan V.K. Multiple scattering of electromagnetic waves by randomly distributed and oriented dielectric scatterers. Phys. Rev. D, 1980, v.21, p.388–394.

[487] Varadan V.V., Varadan V.K., Ma Y., Steele W.A. Effects of nonspherical statistics on EM wave propagation in discrete random media. Radio Sci., 1987, v.22, p.491–498.

[488] Von Ross O. Method for the solution of electromagnetic scattering problems for inhomogeneous dielectrics as a power series in the ratio (dimension of scatterer)/wavelength. J. Appl. Phys., 1971, v.42, p.4197–4201.

[489] Wagner N.J., Fuller G.G., Russel W.B. The dichroism and birefringence of a hard-sphere suspension under shear. J. Chem. Phys., 1988, v.89, p.1580–1587.

[490] Wait J.R. Electromagnetic scattering from a radially inhomogeneous sphere. Appl. Sci. Res. B, 1963, v.10, p.441–450.

[491] Wait J.R. Scattering of a plane wave from a circular dielectric cylinder at oblique incidence. J. Can. Phys., 1955, v.33, p.189–195.

[492] Walstra P. Approximation formulae for the light scattering coefficient of dielectric spheres. Brit. J. Appl. Phys., 1964, v.15, p.1545–1552.

[493] Wang D.-S., Barber P.W. Scattering by inhomogeneous nonspherical objects. Appl. Opt., 1979, v.18, p.1190–1197.

[494] Wang D.-S., Chen H.C.H., Barber P.W., Wyatt Ph.J. Light scattering by polydisperse suspensions of inhomogeneous nonspherical particles. Appl. Opt., 1979, v.18, p.2672–2678.

[495] Wang J.J.H. Generalized moment methods in electromagnetics. New York: Wiley, 1991.

[496] Waterman P.C. Matrix formulation of electromagnetic scattering. Proc. IEEE, 1965, v.53, p.805–812.

[497] Waterman P.C. Matrix methods in potential theory and electromagnetic scattering. J. Appl. Phys., 1979, v.50, p.4550–4565.

[498] Waterman P.C. Scattering by dielectric obstacles. Alta. Freq., 1969, v.38, p.348–352.

[499] Waterman P.C. Symmetry, unitarity and geometry in electromagnetic scattering. Phys. Rev. D, 1971, v.3, p.825–839.

[500] Weil H., Chu C.M. Scattering and absorption by thin flat aerosols. Appl. Opt., 1980, v.19, p.2066–2071.

[501] Westcott B.C. Electromagnetic wave propagation in spherically stratified isotropic media. Electron. Lett., 1968, v.4, p.572–573.

[502] Whitehead J.B., Zumer S., Doane J.W. . Light scattering from a dispersion of aligned nematic droplets. J. Appl. Phys., 1993, v.73, p.1057–1065.

[503] Wiscombe W., Mugnai A. Exact calculations of scattering from moderately-nonspherical Tn-particles: comparisons with equivalent spheres. in Light scattering by irregularly shaped particles. Ed. by D.W. Schuerman. New York: Plenum Press, 1980, p.141–152.

[504] Wyatt Ph.J. Light scattering from objects with spherical symmetry. in Electromagnetic scattering. Ed. by M.Kerker. New York: Pergamon Press, 1963, p.25–35.

[505] Wyatt Ph.J. Scattering of electromagnetic plane waves from inhomogeneous spherically symmetric objects. Phys. Rev., 1962, v.127, p.1837–1843.

[506] Yaghjian A.D. Electric dyadic Green's functions in the source region. Proc. IEEE, 1980, v.68, p.248–263.

[507] Yeh C. Perturbation approach to the diffraction of electromagnetic waves by arbitrarily shaped dielectric obstacles. Phys. Rev., 1964, v.135, p.1193–1201.

[508] Yeh C., Colak S., Barber P.W. Scattering of sharply focused beams by arbitrarily shaped dielectric particles: an exact solution. Appl. Opt., 1982, v.21, p.4426–4433.

[509] Yung Y.L. Rayleigh scattering. Appl. Opt., 1981, v.20, p.533–535.

[510] Yung Y.L. Variational principle for scattering of light by dielectric particles. Appl. Opt., 1978, v.17, p.3707–3709.

[511] Zardecki A., Gerstl S.A.W. Multi-Gaussian phase function model for off-axis laser beam scattering. Appl. Opt., 1987, v.26, p.3000–3004.

[512] Zhang H. Approximate calculation of extinction coefficient. J. Phys. D, 1990, v.23, p.1735–1737.

[513] Zumer S. Light scattering from nematic droplets: anomalous diffraction approach. Phys. Rev. A, 1988, v.37, p.4006–4015.