

V. A. Babenko, L. G. Astafyeva and V. N. Kuzmin

Electromagnetic Scattering in Disperse Media

Inhomogeneous and Anisotropic Particles



Springer

Published in association with
Praxis Publishing
Chichester, UK



Contents

Preface	xi
Acknowledgments	xv
Abbreviations	xvii
List of figures	xix
List of tables	xxv
1 Coordinate and momentum representations in the theory of light scattering by disperse media	1
1.1 Differential and integral equations of electromagnetic scattering	1
1.2 Light scattering by particle collections	8
1.2.1 Equations for multiple scattering waves	8
1.2.2 Statistical characteristics of scattered waves	12
1.3 Electromagnetic scattering by a homogeneous spherical particle in coordinate and momentum representations	19
1.4 Calculated characteristics of scattered light	34
1.5 Computational aspects of the Mie problem	38
1.5.1 General considerations	38
1.5.2 Bessel functions	39
1.5.3 Calculation of angular functions	48
2 Model concepts in aerosol optics	51
2.1 General information on atmospheric aerosols	52

2.2	Microphysical model of aerosols.	53
2.3	Complex refractive index of aerosol particles	56
2.4	Continental aerosols and homogeneous and inhomogeneous particle models	59
2.5	Equilibrium radius of water-containing particles	63
3	Light scattering and absorption by two- and multilayered spheres	72
3.1	Light scattering by a two-layered spherical particle	73
3.2	Effects of core and shell radii and optical constants on absorption of radiation by two-layered particles	81
3.3	Effects of core and shell radii and optical constants on scattering and extinction by two-layered particles	90
3.4	Specific features of light scattering and absorption by hollow particles.	98
3.5	Recursive algorithms to calculate the characteristics of scattered and internal fields for multilayered spheres.	103
3.5.1	Formal solution, set of linear equations.	104
3.5.2	Algorithm and computer code structure.	111
4	Light scattering by water-containing atmospheric aerosol particles.	116
4.1	Calculation of light scattering and absorption by polydisperse ensembles of homogeneous and inhomogeneous particles.	116
4.2	Extinction, scattering, and absorption coefficients for polydisperse systems of TLPs and HPs.	121
4.3	The possibility of purposefully changing the effectiveness of extinction and absorption by systems of layered particles	130
4.4	Influence of water content on angular characteristics of light scattering by aerosols.	138
4.5	Comparison of scattering angular characteristics of TLP and HP ensembles.	145
4.6	Scattering angular characteristics of water-containing particle ensembles and comparisons with experimental results	158
5	Integral characteristics of absorption by spheres	164
5.1	Absorption in selected regions of the particle: volume and surface integral representations.	165
5.2	Kattawar–Eisner formula	168
5.3	Angle-averaged intensity of internal field	172
5.3.1	Theory	172
5.3.2	Some results	174
5.4	The absorption asymmetry	181
5.4.1	Theory	181
5.4.2	Some results	185
5.5	Absorption in the restricted region of the spherical particle	190

6	Internal intensity distributions for homogeneous spherical particles	200
6.1	Intensity distribution inside water droplets	201
6.2	Internal fields of metallic particles.	212
6.3	Features of electromagnetic fields inside particles with $n < 1$. . .	216
6.4	Analyses of the effects of absorption on spatial structures of MDRs in spherical micro-particles	219
6.5	Similarity criterion for optical fields in weakly absorbing spherical aerosol particles	226
7	Internal intensity distributions inside spherical two-layered particles (TLPs)	232
7.1	Absorption and energy distribution inside metallic particles with oxide films	232
7.2	Absorption of IR radiation and optical fields inside hollow metallic and metallized particles	240
7.3	Absorption resonances for HOPs	242
8	Light scattering by radially inhomogeneous particles	247
8.1	Solution of the problem of light scattering by spherical particles with smooth radial optical inhomogeneity	247
8.2	Comparison of light scattering characteristics of the aerosol RIPs, HPs, and TLPs	256
8.3	Comparison of scattering by systems of atmospheric RIPs and systems of HPs and TLPs	263
8.4	Light scattering by spheres with homogeneous cores and RI shells	268
8.4.1	Formal solution	268
8.4.2	Solution for power profile.	272
8.4.3	Algorithm for power profile	277
8.5	Asymptotic model of a fractal cluster	279
8.5.1	What is a fractal cluster.	279
8.5.2	Model construction	281
9	Light scattering by weakly inhomogeneous and weakly anisotropic particles	291
9.1	Modified diffraction equation and the Born distorted wave approximation for radially-inhomogeneous particles (RIPs)	292
9.2	Anisotropic particles in the atmosphere	294
9.3	Light scattering by weakly anisotropic spherical particles.	297
9.4	Amplitude scattering matrix for spherical APs.	302
9.5	Integral scattering characteristics for ensembles of APs	308
9.6	Angular characteristics of light scattering by systems of APs . . .	314

10 Some practical aspects of light scattering by inhomogeneous and anisotropic particles	321
10.1 Detection of adsorbed layers on particle surfaces and estimation of their thickness.	321
10.2 Dispersion light filters with TLP's.	327
10.3 Quasi-homogeneity of scattering media and IR radiation monochromatization.	337
10.4 Christiansen effect in disperse media with APs	343
Appendix A The Riccati–Bessel functions	349
A.1 The definition of Bessel functions	349
A.2 Recursions and asymptotes	350
A.3 Quadratic combinations	353
A.4 Indefinite integrals	354
Appendix B Basic expressions on associated Legendre polynomials	359
B.1 Definition of the associated Legendre polynomials and the angular functions	359
B.2 Symmetry over argument and values for some particular arguments	360
B.3 Recursions	364
B.4 Indefinite integrals for the quadratic combinations of the angular functions	367
B.5 Definite integrals over the quadratic combinations of angular functions	369
Appendix C Vector spherical wave functions	379
C.1 Definition of vector spherical wave functions	379
C.2 Integrals for the vector angular wave functions	380
C.3 Integrals for the vector spherical wave functions	381
Appendix D Guide to our light scattering codes	383
Appendix E Light scattering codes on the Internet	385
References	388
Index	421