

# Index

---

- Absorption:
  - by atmospheric aerosols, 436–446
  - dominance of, in Rayleigh limit, 309
  - effect on ripple and interference structure, 306, 318
  - méchanisms in bulk matter, summary, 282
  - temperature effects on, 281
- Absorption coefficient, bulk matter:
  - defined, 29
  - measurement of, 29, 30
- Absorption cross section:
  - of cubes, 368
  - defined, 71
  - of distribution of ellipsoids, 353–356
  - of ellipsoids, Rayleigh limit, 150–152, 345, 348
  - integrated, of ellipsoid, 347
  - in Rayleigh-Gans approximation, 161, 162
  - of sphere, Rayleigh limit, 140
  - of spheroid, 313
  - of weakly absorbing large sphere, 166–169
- Absorption edge, *see* Band gap
- Absorption efficiency:
  - defined, 72
  - and emissivity, 125
  - greater than 1, 339–342
  - of small sphere, 136
  - of sphere, asymptotic limit, 172, 173
  - of water droplets, 170, 171
- Aggregation of particles:
  - effect on extinction spectra:
    - aluminum, 376
    - amorphous quartz, 361
    - gold, 372
    - magnesium oxide, 366–368
  - effect on optical properties, 81, 315, 342, 258
  - and sampling of atmospheric aerosols, 440
  - scattering by, spherical clusters, 423–425
- Albedo, single scattering:
  - defined, 445
  - and global climate, 435, 442, 443–446
- Alexander's dark band, 177
- Alignment of particles:
  - in interstellar dust clouds, 463–465
  - in noctilucent clouds, 451
  - in ocean waters, 427
- Aluminum:
  - bulk optical properties of, 225, 271–273, 353
  - particles, extinction by:
    - ellipsoids, 346
    - measurements, 374–377
    - spheres, 294, 295, 310, 338, 375
  - surface plasmons in, 338, 339
- Amorphous solids:
  - and far-infrared emission, 446
  - as oxide coating, 376
  - particles of, in interstellar dust, 462–466
- Amplitude scattering matrix:
  - for anisotropic dipole, 154
  - for cylinder, 202, 205, 408
  - Rayleigh limit, 208
  - defined, 63
  - for optically active particles, 189, 408
  - in Rayleigh-Gans approximation, 161, 407
  - for sphere, 112
    - Rayleigh limit, 132, 140, 407
  - and sum rule, 154
  - symmetry of, 406–412
- Angle-dependent functions, in Mie theory:
  - defined, 94
  - polar plots of, 96
  - recurrence relations for, 95, 119
- Angular scattering:
  - calculations:
    - for spheres, 114, 115
    - distributed in size, 387–389
    - of increasing size, 384–387
    - in Rayleigh limit, 133, 134
    - for spheroids, 397–400
  - measurements:
    - absolute and relative, 391
    - applicability of Mie theory to, 427, 428

- for cylinder, 426
  - for nonspherical particles, 399–401, 422
  - for spheres, 420, 421
  - techniques for, 389–392
- Anisotropic cylinder, scattering by, 209
- Anisotropic oscillator model:
  - applied to crystalline quartz, 250, 251
  - theory of, 247–249
- Anisotropic solids, powders of, 432
- Anisotropic sphere, scattering by, 152, 153, 184, 185
- Asymmetry:
  - in absorption bands, 306–308
  - in scattering diagrams, 115, 384–389, 398–400
- Asymmetry parameter:
  - defined, 72
  - for nonspherical particles, 401
  - for spherical particles, 119, 120
- Asymptotic limits:
  - of absorption and scattering efficiencies, 171–173
  - of extinction efficiency, 107, 110, 172, 299
- Atmospheric aerosols:
  - absorption by, 436–446
  - and blue moon, 129
  - and climate, 434–436
  - imaginary part of refractive index of, 279, 436–439
  - remote sensing of, 442, 443
- Average dielectric function, theories of:
  - Bruggeman, 217, 218
  - Maxwell Garnett, 214–218
  - see also* Effective refractive index
- Average refractive index of atmospheric aerosols, 433, 438
- Babinet's principle, 108
- Backscattering:
  - by nonspherical particles, 422, 423
  - by sphere, 122
- Backscattering cross section, *see* Radar backscattering cross section
- Band gap:
  - defined, 251, 252
  - in magnesium oxide, 270
  - in semiconductors, 282
  - superconducting, 282, 376
- Beam width, effect of on scattering, 117, 118
- Bessel functions:
  - of complex order, 185
  - of integral order, 195
  - asymptotic expansions for, 93, 94
  - computation of, 492, 493
  - expansion of trigonometric functions in, 418
  - integral representation of, 110, 164, 197
  - power series expansions for, 208
  - recurrence relation for, 197
- spherical (half-integral order):
  - computation of, 478
  - integral representation of, 92
  - plots of, 88
  - power series expansions for, 130, 131
  - recurrence relations for, 86, 478
  - and Riccati-Bessel functions, 101
  - stability of recurrence relations for, 127, 128
- Biological particles, scattering by, 395, 397, 425, 427
- Birefringence:
  - circular, 46, 191
  - of ice, 179
  - linear, 45, 248
- Blackbody radiation, *see* Planck function
- Blue moon and blue sun, 107, 129, 318
- Boundary conditions for electromagnetic fields, 59–61, 99, 182
- Brewster angle, 36, 135
- Bruggeman average dielectric function, 217, 218
- Bubble, resonance condition for, 331
- Bulk optical constants, applicability of to small particles, 280, 326, 336, 360, 371, 372
- Carbon particles:
  - and absorption by atmospheric aerosols, 438, 439, 444–446
  - absorption by small spheroids of, 351–353
  - and complex refraction index of carbon, 431
  - in India ink, 288
- Causality, 19, 22, 56, 116
- Charged sphere, scattering by, 118
- Christiansen effect, 292
- Cigarette smoke, blue moon demonstrated with, 129
- Circular cylinder, *see* Cylinders, scattering by
- Circular dichroism:
  - defined, 46, 191
  - in particulate media, 192–194
- Circumstellar dust shells, 457, 462, 463
- Clausius-Mosotti relation, 221
- Climate changes, 434–436
- Clusters of spheres, scattering by, 423–425
- Coated ellipsoid, scattering by in Rayleigh limit, 148–150

- Coated sphere, scattering by:
  - computer program for, 483–489
  - and immunological slide, 470–472
  - and invisible particles, 149
  - in Rayleigh limit, 149
  - and surface modes, 329, 330
  - theory of, 181–183
- Cole-Cole plots, 265, 351, 352
- Colloids, optical properties of, 369–374
- Color:
  - of copper, 259
  - of gemstones, 271
  - of glacial crevasses, 276
  - of Grand Canyon, 271
  - of metal colloids, 369, 371
  - of noctilucent clouds, 448
  - of old bottles, 271
  - of rainbow, 177, 188
  - of sky, 42
  - of swimming pools, 274
- Color centers, 271, 282, 283
- Computer programs for scattering and
  - absorption, 475, 476
  - by coated sphere, 483–489
  - by homogeneous sphere, 477–482
  - by normally illuminated infinite cylinder, 491–497
- Conductivity, 13, 15, 19, 186
  - surface, 118
- Convergence criteria in scattering
  - calculations, 126, 477, 485
- Convolution theorem, 17
- Copper, 259, 337, 352, 353
- Core electrons, 267, 273
- Cross polarization:
  - defined, 383
  - and depolarization ratio, 403
  - and particle shape, 423
  - in Rayleigh-Gans approximation, 407
  - of sphere, 408
- Cross sections:
  - of anisotropic sphere, 184
  - of arbitrary particle, 71, 73
  - computation of, for spheres, 126–129
  - of cylinder, 202–204
  - of ellipsoid, Rayleigh limit, 151, 152, 343, 350
  - normalization of, 289
  - of optically active sphere, 190
  - in Rayleigh-Gans approximation, 162
  - of sphere, 103
    - Rayleigh limit, 140
  - and surface modes, 343
  - of weakly absorbing large sphere, 166–171
  - see also* Absorption; Extinction; Scattering
- Cube:
  - absorption by, randomly oriented, 386
  - surface modes in, 365–369
- Cylinders, scattering by:
  - finite:
    - according to diffraction theory, 209–213
    - in Rayleigh-Gans approximation, 163–165
  - infinite, 194–213
    - amplitude scattering matrix for, 206
    - anisotropic, 209
    - efficiencies for, 204–207
    - scattering matrix for, 206
- Debye relaxation mode, 259–265
  - dielectric function for, 263, 264
  - and microwave absorption by
    - macromolecules, 472–474
  - and water, 264
- Degree of polarization, *see* Polarization
- Depolarization factors, 147
- Depolarization of scattered light, 67, 403
- Depolarization ratio, 403
- Detailed balance, 125
- Dichroism:
  - circular, 46, 191
  - linear, 46
- Dielectric function:
  - complex:
    - of aluminum, 255, 272, 346
    - anisotropic model for, 247–250
    - average, *see* Average dielectric function, theories of
    - Cole-Cole plots of, 353
    - Debye mode for, 263, 264
    - Drude free-electron model for, 252–256
    - high- and low-frequency limits of, 234
    - of ice, 275
    - Lorentz oscillator model for, 230–232, 241
    - of magnesium oxide, 246, 269
    - multiple oscillator model for, 245
    - quantum mechanical expression for, 245
    - and refractive index, 227
    - relationship of real and imaginary parts
      - of, 266
    - of silicon carbide, 243
    - of silver, 257, 258, 373
    - of water, 264, 275
  - static, 267
- Dielectric function tensor, 152, 247, 249
- Differential scattering cross section:
  - defined, 72, 383
  - measurement of, 391, 392

- Diffraction:
  - by aperture, 109
  - by cylinder, 209–213
  - by obstacle, 109
  - by sphere, 110, 111
  - theory of, 107–111
- Dipole:
  - potential of, 138, 139
  - radiation by, 99, 139, 236–238
- Disk:
  - absorption by, 350, 353
  - as oblate spheroid, 146
  - scattering diagram for, diffraction theory, 111
- Dispersion:
  - anomalous, 232, 235, 242
  - normal, 177, 232, 239
  - spatial, 22
- Dispersion relations, *see* Kramers-Kronig relations
- Doppler shift, wind velocity measurements by, 447
- Drude free-electron model, 251–257
  - for aluminum, 255, 256, 272, 273
  - dielectric function for, 252, 254
  - for semiconductors, 256
  - and surface plasmons, 335, 345
- Eccentricity of spheroids, 146
- Effective optical constants, *see* Average dielectric function, theories of
- Effective refractive index:
  - of atmospheric aerosols, 443–446
  - of slab of particles, 78, 79
  - see also* Average dielectric function, theories of
- Efficiency factor:
  - defined, 72
  - greater than 1, 125, 333, 334, 339–342
  - for radiation pressure, 120
  - see also* Absorption; Cross sections; Extinction; Scattering
- Electromagnetic waves, plane, 25–27
- Electron energy bands, 239, 251, 252, 270
- Electrons, free and bound, 257–259
- Electrostatics approximation, 136–154
  - for anisotropic sphere, 152–154
  - for coated ellipsoid, 148, 149
  - for cube, 342, 356, 368
  - for ellipsoid, 141–149
  - for sphere, 136–141
  - and surface modes, 327
- Ellipsoidal coordinates, 141
- Ellipsoids:
  - aluminum, 346
  - coated, 148–150
  - continuous distribution of, 353–356
  - as disks, needles, and spheres, 348–353
  - in electrostatics approximation, 141–149
  - metallic, 345–347
  - polarizability tensor for, 150
  - randomly oriented, 151, 152, 346
  - surface modes in, 342–356
- Ellipsometric parameters of polarized light, 46
  - and Stokes parameters, 50
- Ellipsometry, 41, 56
  - and light-scattering measurements, 416
- Emissivity of sphere, 125
  - greater than 1, 126
- Exciton, 269, 270
  - pressure dependence of, 468, 469
- Extinction:
  - defined, 69, 287
  - interpreted, 69, 75, 287
  - paradox, 107, 110, 129
  - by sphere in absorbing medium, 330
  - sum rule for, 116, 117
  - theorem, Ewald-Oseen, 5, 11
- Extinction calculations:
  - for cylinders, 314–316
  - for distribution of ellipsoids, 356
    - of aluminum, 375
    - of magnesium oxide, 367, 368
    - of quartz, 363
    - of silicon carbide, 364
  - for spheres:
    - of aluminum, 294, 295, 310, 338, 375
    - effect of absorption on, 307
    - effect of size distribution on, 296–299
    - of electron-hole droplets, 377, 378
    - of gold, 370, 371
    - of magnesium oxide, 290–292, 308, 367
    - of quartz, 361, 363
    - and ripple structure, 300, 301, 302
    - of silicon carbide, 333, 334
    - of water, 104–107, 292, 297, 309
    - see also* Mie calculations
  - for spheroids, 311–314
- Extinction cross section defined, 71
  - see also* Cross sections; Scattering cross sections and efficiencies
- Extinction measurements:
  - for amorphous quartz spheres, 360–362
  - for colloidal gold, 371
  - for colloidal silver, 373, 374
  - for cylinders, microwave, 322, 323
  - for electron-hole droplets, 377, 378

- for interstellar dust, 458–462
- for irregular quartz particles, 318, 319, 362, 363
- for irregular silicon carbide particles, 364, 365
- for magnesium oxide cubes, 366, 367
- for nonspherical aluminum particles, 375–377
- for sphere in microwave cavity, 303, 304
- for spheroids, microwave, 321, 322
- Fiber, scattering by, 425, 426
- Fluctuations, scattering by, 6
- Fogs, scattering by, 116, 387–389
- Form factors in Rayleigh-Gans theory, 161
  - for finite cylinder, 164, 165
  - for sphere, 163
- Forward scattering:
  - dominance of, for large particles, 114–116, 384, 387, 398
  - effect on measured extinction, 75, 110, 111, 289, 316
  - and polarization, 206
- Fourier transforms, 15–19, 23, 56
- Fraunhofer diffraction, 109
- Free electrons, *see* Drude free-electron model
- Fresnel formulas for reflection and transmission, 34, 35
  - and scattering by large sphere, 167
- Fröhlich mode:
  - absorption at, 328
  - of bubble, 331
  - defined, 327
  - effect of coating on, 329, 330, 471
  - effect of finite size on, 329
  - effect of medium on, 332
  - frequency of, 327
  - of void, 330
  - width of, 332
- see also* Surface modes; Surface plasmons; Surface phonons
- Geometrical factors of ellipsoid, 146–147
  - and depolarization factors, 147
  - and eccentricity of spheroids, 146, 147
  - and surface modes, 343, 344
- Glory, 389
  - and nonspherical particles, 401
- Gold, 337, 352, 353
  - colloidal extinction by, 369–372
- Graphite:
  - in interstellar dust, 459–461
  - surface plasmon in, 379
- Greenhouse effect, 435
- Green's function, 263
- Group velocity, 253
- Haloes, ice-crystal, 178–180
- Hankel functions, 93, 94
- Ice:
  - absorption bands of, 277, 278
  - dielectric function of, 275
  - in interstellar dust, 462, 467
- Ice-water mixtures, 218
  - and radar backscattering, 265, 276
- Immunological slide, 469
- Impurities, absorption by, 270, 271, 279
- Inhomogeneous particles, dielectric functions for, 213–219
- Integrating plate method, 440, 441
- Integrating sphere, 320, 441
- Interference bands, in thin slabs, 38, 39
- Interference structure in extinction, 104–106, 292–299
  - effect of absorption edge on, 306
  - for polystyrene spheres, 317, 318
  - and response curves for sizing particles, 404, 405
  - for spheroids, 311, 312
- Interstellar dust, 307, 457–467
  - and circular polarization, 464, 465
  - and diffuse bands, 459, 460
  - emission by, 462, 466
  - extinction by
    - average, 459
    - infrared, 461
    - ultraviolet, 460
  - and linear polarization, 463, 464
  - scattering by, 465, 466
- Inverse scattering problem, 10, 11, 403
- Invisible particles, 149, 150
- Irregular particles:
  - extinction by, measurements, 318, 319
  - scattering by, measurements, 400, 402
- KBr pellet technique, 358–360
- Kirchhoff's law for emission and absorption, 125
- Kramers-Kronig relations, 19–22, 41, 56, 274
  - and Debye model 263
  - and dielectric function, 266
  - and optical activity, 191
  - and oscillator model, 231
  - for reflection, 32, 33, 234
  - for refractive index, 28
- Legendre functions, 86, 90, 91

- Levitation of particles, 394, 395
  - by radiation pressure, 304, 305
- Lidar, 443, 447
- Light sources, for scattering, 390
- Limiting behavior:
  - of backscattering efficiency, 123
  - of dielectric function, 266, 267
  - of efficiencies:
    - for large sphere, 107–110, 171–173
    - for small sphere, 130–136
  - of harmonic oscillator model, 234, 235
- Logarithmic derivative:
  - computation of, 478
  - defined, 127, 204
  - recurrence relation for, 127, 205
- Lorentz oscillator model, 228–232
  - for core electrons, 272
  - dielectric function for, 230, 231, 241
  - for magnesium oxide, 240, 246
  - for silicon carbide, 241–243
  - and surface modes, 332, 348
- Lyddane-Sachs-Teller relation, 244
- Magnesium oxide:
  - bulk optical properties of, 239–241, 245–247, 268–271
  - extinction calculations for, 290–292, 367
  - extinction measurements for, 365–369
  - particle production technique for, 359
- Magnetic dipole, contribution of to absorption, 310
- Magnetic particles, 141
- Matrices, for isolating particles, 358–360
- Maxwell equations, 12, 58
  - Fourier transform of, 16
  - for optically active media, 186
  - plane-wave solutions to, 26
- Maxwell Garnett average dielectric function, 214–219, 359, 444, 470
- Mean free path of electrons:
  - limited by particle size, 336–368, 370–372
- Microwave analog technique:
  - for angular scattering, 395–397
  - for extinction, 320–323
- Microwave radiation:
  - cavity absorption of, 303, 304
  - effect of on biological materials, 472, 473
  - scattering of, measurements, 395–397, 400, 402
  - see also* Microwave analog technique
- Mie calculations, 126–129
  - computer programs for, 477–482
  - see also* Extinction calculations, for spheres
- Mie theory, 83–104, 111–114
  - applicability of to nonspherical particles, 427, 428
  - history of, 82, 129, 369
- Modes, electromagnetic, 97–100
  - and laser levitation experiments, 305
  - transverse electric, 97, 98
  - transverse magnetic, 97, 98
- Mueller matrices, 53–56, 417
  - for circular polarizer, 56
  - for linear polarizer, 54
  - for linear retarder, 55
- Mueller scattering matrix, *see* Scattering matrix
- Multiple-oscillator model, 244–247
  - for magnesium oxide absorption bands, 308
  - for quartz reflectance, 250, 251
- Multiple scattering, 9
  - and circular polarization, 451
  - and extinction, 80
- Needle:
  - absorption by, 350, 352
  - as prolate spheroid, 146
- Nephelometers:
  - integrating, 439
  - polar, 389–391, 414–419
- Noctilucent clouds, 448–454
- Nonspherical particles:
  - angular scattering by, 397–401
  - calculational techniques for, 220–222
  - and cross polarization, 401–403
  - extinction calculations for, 310–316
  - extinction measurements for, 318, 319
  - scattering matrix for, 421–427
  - see also* Cube; Disk; Ellipsoids; Needle
- No-phonon bands, 271, 282
- Ocean waters, scattering by, 425, 427
- Optical constants:
  - of aluminum, 255, 272, 346
  - of atmospheric aerosols, 430–434
  - defined, 27, 28
  - experimental determination of, 41, 56
  - Kramers-Kronig relations for, 28
  - Lorentz oscillator model for, 231
  - of magnesium oxide, 240, 245–247, 269
  - at microwave frequencies, 396
  - of powder samples, 430, 431
  - relation to dielectric function, 227
  - of silicon carbide, 242
  - from single-particle measurements, 431
  - of water, 275
  - see also* Dielectric function; Refractive index, complex

- Optically active particles, 185–194
  - cross sections for, 190
- Optical rotation:
  - defined, 191
  - by particulate medium, 78, 192–194
- Optical theorem, 71, 73
  - and absorption in Rayleigh-Gans approximation, 161
  - for cylinder, 204
  - and diffraction theory, 109, 110
  - for dipole, 150
  - for sphere, 112
  - and sum rule for extinction, 116
- Oscillator model, *see* Lorentz oscillator model
- Particle production, 392–394
  - aluminum, 376
  - by arc vaporization, 359
  - by burning magnesium, 365
  - by grinding, 359, 360
  - of monodisperse aerosols, 393, 394
  - with nebulizers, 393, 394
  - with vibrating orifice, 393, 394, 405
- Perturbation techniques, 220
- Phase, measurement of, 321
- Phase function:
  - defined, 72, 384
  - for finite cylinder, 210–212
  - for infinite cylinder, 212, 213
  - for spheres, 384–389
  - see also* Angular scattering
- Phase matrix, 66
  - see also* Scattering matrix
- Phase velocity:
  - defined, 25
  - and refractive index, 235–238
- Phonons, 233
  - see also* Surface phonons
- Photoacoustic technique, 292, 320, 441, 442
- Photographic process, 372
- Photosensitive glass, 374
- Planck function, 123–125, 435
- Plane waves, 25–27
  - expansion of in vector cylindrical harmonics, 195–197
  - expansion of in vector spherical harmonics, 89–93
  - propagation of, 28–30
  - reflection and transmission of, 30–41
- Plasma frequency:
  - for aluminum, 256
  - defined, 230
  - for ionosphere, 256
  - for lattice vibrations, 241
  - and longitudinal oscillations, 253, 254
  - for semiconductor impurities, 256
  - shift of because of bound charges, 259
  - for silicon, 256
  - tables of, 257, 379
- Plasmons, 233
  - see also* Surface plasmons
- Point matching method, 220
- Polarization, 44–56
  - degree of, 53
    - circular, 53
    - linear, 53
  - measurement of, 54
  - and ellipsometric parameters, 44–46
  - upon reflection, 36
  - see also* Mueller matrices; Stokes parameters
- Polarization, of scattered light:
  - in backward direction, 206, 456
  - in forward direction, 206
  - from noctilucent clouds, 449–453
  - by nonspherical particles, 401–403
  - at rainbow angle, 388, 389
  - by sphere, 113–115
    - Rayleigh limit, 135
  - see also* Scattering matrix
- Polarization modulation, 416–419
  - in astronomy, 464
- Polarizers:
  - Mueller matrices for, 54, 56
  - and scattering matrix elements, 415
  - and Stokes parameters, 47–49
- Polystyrene spheres:
  - measured extinction by, 317, 318
  - measured matrix elements for, 419, 420
  - for nephelometer calibration, 391
- Poynting vector, 23, 24
  - field lines of, 339–342
- Purcell-Pennypacker method, 220, 221
- Quantum size effects, 280, 369, 372, 376
- Quartz:
  - amorphous:
    - infrared extinction measurements for, 360–362
    - particle production, 359
  - crystalline:
    - infrared extinction measurements for, 362, 363
    - reflection by, 250
    - visible and ultraviolet extinction measurements for, 318, 319

- Radar backscattering:
  - from birds, 123
  - dependence on polarization, 456
  - from melting ice, 265
  - and rainfall measurements, 454–457
  - reflectivity factor, 455
  - from thunderstorms, 276
- Radar backscattering cross section, 120–123
- Radar backscattering efficiency
  - asymptotic limit, 123
  - and correctness of computations, 478, 485
  - defined, 122
  - for sphere, 122
  - Rayleigh limit, 135
- Radiation damage, 269–271, 290–292, 308
- Radiation pressure, 120
  - and levitation experiments, 304, 305, 394, 395
- Radio wave propagation, ionosphere, 256
- Rainbows, 174–177, 180
  - polarization of, 387–389
- Rainfall, measurement of, 454–457
- Rayleigh-Gans approximation, 158–165
  - and biological particles, 425
  - for finite cylinder, 163–165
  - for optically active particles, 165
  - for sphere, 162, 163
- Rayleigh scattering, 6, 7, 132–134
  - according to Rayleigh, 133
- Rayleigh smoothness criterion, 39
- Ray tracing diagram, for sphere, 167
- Reciprocity relation, 409
- Recurrence relations:
  - for Bessel functions, 86, 197, 478
  - for logarithmic derivative, 127, 205
  - stability of, 128, 477, 478
- Reddening, 106, 107, 299
  - by interstellar dust, 458
  - by MgO smoke, 290
  - by milk, 106
  - by polystyrene spheres, 317, 318
  - and sunsets, 107
- Reflectance:
  - of aluminum, 35, 255, 272
  - of magnesium oxide, 240, 246
  - and optical constants measurements, 41
  - of platinum, 241
  - of quartz, 250
  - of silver, 257, 258
  - of water, 35
- Reflection:
  - and backscattering, 123
  - diffuse, 39, 441, 442
  - Fresnel formulas for, 34, 35
  - Kramers-Kronig relations for, 33
  - of normally incident light, 30–33
  - of obliquely incident light, 33–36
  - and penetration depth, 241
  - by slab, 36–41
  - specular, 39
  - by sphere, 171–174
- Reflection cross section, 172
- Reflection efficiency, 172
  - for nonabsorbing sphere, 174
- Refraction:
  - and determination of optical constants, 41
  - by prism, 178, 179
  - Snell's law for, 34
- Refractive index, complex, 27, 227
  - real part less than 1, 235–239
  - see also* Optical constants
- Remote sensing, atmospheric aerosols, 442, 443
- Response function, light scattering
  - instrument, 404, 405
- Reststrahlen*, 244, 245
  - bands in MgO, 270
  - bands in quartz, 250
  - temperature dependence of, 281
- Ripple structure:
  - in absorption, 293, 294, 303, 304
  - in extinction, 105, 106, 293, 294, 296–298, 300–304, 318
  - in extinction by spheroids, 311, 312
  - in radiation pressure, 304, 305
  - in scattering, 302
- Scattering:
  - azimuthally dependent, 397, 399, 428
  - coherent, in forward direction, 68
  - elastic, 7
  - incoherent, 9, 76
  - multiple, 9
  - physical basis for, 3, 4
  - plane, 61, 62
  - single, 9
- Scattering amplitude, 70, 71
  - see also* Amplitude scattering matrix
- Scattering cell, 392
- Scattering coefficients:
  - for coated sphere, 183
  - computation of, 126–129
  - for cylinder, 198, 199
  - fine structure in, 301–304
  - for homogeneous sphere, 99–101, 114
  - for optically active sphere, 180
  - vanishing of denominators of, 100, 101, 106, 326



- Scattering cross sections and efficiencies
  - for arbitrary particle, 71, 72, 73
  - asymptotic values of, 171–173
  - for cylinder, 204
  - for disks, needles, and spheres, Rayleigh limit, 350
  - for magnesium oxide spheres, calculated, 291
  - of obstacle, diffraction theory, 110
  - for optically active sphere, 190
  - for randomly oriented ellipsoid, Rayleigh limit, 152
  - for sphere, 103
    - Rayleigh limit, 135, 136, 140
  - for spheroids, calculated, 312–314
  - see also* Cross sections
- Scattering diagram, 72
- Scattering matrix, 63–69
  - for anisotropic dipole, 154–157
  - for arbitrary particle, 65
  - for cylinder, 206, 408
  - inequalities satisfied by elements of, 406, 407
  - measurements of, 414–427
    - for artificial fogs, 420
    - for bacterial spores, 425, 427
    - for clusters of spheres, 423–425
    - for nonspherical particles, 421–427
    - for polystyrene spheres, 419, 420
    - for quartz fiber, 425, 426
    - techniques for, 414–419
    - for water droplets, 419–421
  - for optically active sphere, 408
  - in Rayleigh-Gans approximation, 407
  - for sphere, 112, 408
    - Rayleigh limit, 132
  - symmetries of, 406–414
- Separation of variables, 219, 220
- Shape, dependence of optical properties on:
  - extinction, 310–316, 318–323
  - scattering matrix elements, 428
  - surface modes, 342–344, 356, 357, 363–369, 373–377
  - see also* Nonspherical particles
- Signal velocity, 236
- Silicon carbide:
  - emission by, in interstellar dust, 462, 463
  - lattice vibrations in, 241–244
- particles:
  - extinction by:
    - ellipsoids, 349, 364
    - fibers, 365
    - measurements of, 364
    - spheres, 332–334
    - production of, 359
- Silver:
  - bulk optical properties of, 257–259, 352, 353
  - colloid, extinction by, 372–374
- Single particles, measurements on, 303, 304, 321–323, 394–397, 423–426
- Sizing of particles, 403–406
  - by angular scattering, 384
  - by extinction, 318
  - by forward scattering, 401, 405
- Skin depth, 310
- Skylight:
  - color of, 42, 107
  - polarization of, 157
- Smoke:
  - aluminum, 376
  - carbon, 320
  - MgO, SiO<sub>2</sub>, SiC, 359
  - screens, 434
- Sphere:
  - anisotropic, 184, 185
  - coated, 181–183
  - cross sections for, 103
  - polarization by, angle dependent, 113, 115, 385, 386, 388
  - in Rayleigh approximation, 130–141
  - in Rayleigh-Gans approximation, 162, 163
  - scattering by, angle dependent, 114, 115, 384–389
  - scattering coefficients for, 100, 101, 114
  - scattering matrix for, 112
  - in uniform electrostatic field, 137
  - see also* Angular scattering; Extinction calculations; Scattering cross sections and efficiencies
- Spheroids:
  - angular scattering by, calculated, 397–399
  - extinction by:
    - calculated, 311–314
    - measured, 320–322
  - geometrical factors for, 147
  - surface modes in, 344
- Stationary phase, method of, 74, 78, 79
- Statistical theory of scattering, 222
- Stokes parameters, 46–53
  - in circular polarization representation, 191
  - example of use of, 417
  - of scattered light, 64–67
  - two systems for, 382
- Sum rule:
  - for extinction, 116, 117, 129
  - for susceptibility, 22, 267

- Supernumerary bows, 177
- Superposition, 60, 61
- Surface modes, 325–389
  - in aluminum spheres, 338, 339
  - in cubes, 368
  - defined, 326
  - effect of coating on, 329, 330
  - effect of shape on, 357
  - effect of size on, 329, 333
  - in ellipsoids, 342–356
  - and lidar backscattering, 447, 448
  - in magnesium oxide particles, 292, 365–369
  - in metallic spheres, 335, 336
  - in nonspherical particles, 342–356
  - and one-oscillator mode, 331–334
  - in scattered light, observed, 374
  - in silicon carbide particles, 333, 334, 364, 365
  - in spheres, 326–329
  - in voids and bubbles, 330, 331
  - see also* Fröhlich mode; Surface phonons; Surface plasmons
- Surface phonons, 336
- Surface plasmons, 335
  - in gold, 369–372
  - in indium, application to immunology, 469–472
  - in silver, 372–374
  - table of, 379
- Suspension of particles, *see* Levitation of particles
- Symmetry:
  - operations on particle, 409–412
  - of scattering matrices:
    - for collections of particles, 412–414
    - for obliquely illuminated cylinder, 408
    - for ocean waters, 425, 427
    - for optically active sphere, 408
    - in Rayleigh-Gans approximation, 407
    - for sphere, 408
    - for sphere, Rayleigh limit, 407
  - time reversal, 125
- Temperature:
  - effect of on optical properties, 264, 281–283
  - global, effect of atmospheric aerosols on, 434, 435
- Thermal emission, 123, 125
- T-matrix method, 221, 222, 397
- Transmission:
  - diffuse, 440, 441
  - efficiencies for, 174
  - at plane boundary:
    - normally incident light, 30, 31
    - obliquely incident light, 33–36
  - by slab:
    - homogeneous, 36–41
    - particulate, 77–79
- Transparency, ultraviolet, 256
- Units, SI, 12
- Vector cylindrical harmonics, 195
- Vector identities, 83
- Vector scattering amplitude, 70
  - for dipole, 139, 237
- Vector spherical harmonics, 84, 87, 89, 182, 187
  - expansion of plane wave in, 89–93
  - orthogonality of, 90–93
- Vibration ellipse, 45, 47
- Voids, 147, 148
  - surface modes in, 330, 331
- Water:
  - bulk optical properties of, 273–278
  - Debye relaxation in, 264, 276
  - dielectric function of, 275
  - electronic absorption in, 274, 278
  - free molecule, normal modes of, 277
  - transparent region of, 274–276
  - vibrational absorption in, 276–278
- Water droplets:
  - absorption efficiency of, 170, 171
  - extinction by, 105, 292–294, 297, 309
  - polarization by, 115, 385, 386, 388
  - scattering by, 114, 115, 384, 389
  - see also* Angular scattering; Cross sections; Ripple structure
- Wave equation:
  - scalar, 59
    - in cylindrical coordinates, 194
    - in spherical polar coordinates, 84
  - vector, 58, 83, 84
- Waves:
  - longitudinal, 15, 242, 254
  - transverse, 15, 26, 242
- Zinc oxide, 468, 469
- Z-R relations, 455, 456