

# Index

- Abbott, D. C., 327, 329  
aberration effect, 79, 102–104, 112, 114, 291  
Abramowitz, M., 232  
absorption, 76, 153–158, 230  
    bound–bound, 172  
        power-law distribution, 328  
    bound–free, *see* photoionization  
    free–free, *see* bremsstrahlung, inverse  
    multiphoton, 77  
    negative, 77  
    true, 89  
absorption coefficient, 76  
    line, 124  
    Rosseland mean, 119  
absorptivity, 75–78, 86, 89, 102, 158, 172, 182, 213  
    anisotropic, 78  
    free–free, 170  
    invariant, 106  
    nonrefractive, 217  
    refractive, 215, 216  
    Stokes vector, 226  
accelerated Lambda iteration, *see* ALI  
acceleration equation, 46, 47, 61  
Adams, M. L., 278, 283  
Adams, T. F., 201, 202, 280  
adaptive mesh refinement, *see* AMR  
advection  
    donor-cell, 50  
    flux, 50, 51  
    step, 49, 50  
Ahrens, C., 292  
albedo, 81, 96, 97, 287  
    single-scattering, 89, 183, 202, 315, 318  
Alcouffe, R. E., 282, 290  
ALE, 10–12, 61–62, 67  
    3-D, 62  
    equations, 11  
    grid motion, 61  
    zone  
        mass, 11  
        volume, 11  
algebraic equation, asymptotic solution, 145  
ALI, 126, 286–291  
Allis, W. P., 229  
ALTAIR, 252  
Ambartsumian, V. A., 95  
amplification factor, 44  
AMR, 59–62, 67  
    block-structured, 60, 61  
    cell-based, 61  
AMR refinement criterion, 61  
AMR refinement factor, 60  
angle  
    diffraction, 70  
    polar, 283  
    position, 221  
    solid, 70  
apparatus  
    intensity definition, 70  
    polarization measuring, 218  
approximate operator iteration (AOI), *see* ALI  
arbitrary Lagrangian Eulerian, *see* ALE  
ARES code, 62  
astrophysics, stellar, 206  
Athay, R. G., 179, 191, 192, 273  
atmosphere  
    hydrostatic, 141  
    oscillations  
        with radiation pressure, 141–151  
    semi-infinite, 91  
Atwood number, 19  
Auer, L. H., 192–194, 251, 262, 270, 276, 277, 288  
Avrett, E. H., 186, 189, 191  
Axford, W. I., 304  
balance, local, 81  
Baldwin, C., 246, 254, 256, 257  
Balmer lines, 192  
Balsara, D., 59  
Barbier, D., 99  
barotropic law, 15  
barrier, insulating, 304  
Baschek, B., 133  
Beckers, J. M., 226  
Beer's law, 76  
Bell, J. B., 60

- Berger, M. J., 60  
 Bernoulli constant, 66  
 Bernoulli's law, 15–20  
   strong form, 15, 18  
   weak form, 15  
 Biberman, L. M., 209  
 birefringence, 225  
 Blinnikov, S. I., 131, 133, 135  
 Boltzmann equation, 76  
 Boltzmann law, 156, 183  
 Boltzmann number, 238, 320, 323, 324  
 Born, M., 219  
 Bose–Einstein distribution, 309, 312  
   fugacity, 309  
 boundary  
   free, 44  
   rigid, 44  
   vacuum, 91  
 boundary conditions  
   diffusion, 243  
   Dirichlet, 243, 244, 295, 296  
   extrapolation length, 244  
   hydrodynamic, 44  
   incident intensity, 243  
   Milne, 244  
   Neumann, 243, 244, 296  
   reflection, 244  
   specified flux, 244  
   spherical, 271  
   vacuum, 243  
 boundary layer, 81, 97  
   thickness, 81  
   viscous, 16  
 Boussinesq approximation, 148  
 Bowers, R. L., 41, 49, 50, 61  
 Boyd, J. P., 65  
 Brandt, J. C., 303  
 bremsstrahlung, 168–172  
   inverse, 168–172, 214, 230, 295  
 Brown, F. B., 292  
 Brown, P. N., 259  
 Broyden, C. G., 290  
 Buchler, J.-R., 110–113, 288  
  
 CALE code, 62  
 Calvetti, D., 252  
 Canfield, E. H., 291  
 Canfield, R. C., 191, 273, 274  
 Cannon, C. J., 288  
 Canuto, C., 65  
 capture, radiative, 165  
 Caramana, E. J., 41, 48  
 Carlson, B. G., 281, 283, 284  
 Carlsson, M., 288, 290  
 Castor, J. I., 84, 102, 110, 123, 126, 132, 134, 135,  
   139, 189, 192, 260, 278, 291, 327, 329  
 Cauchy integral formula, 315  
 CFL condition, 44, 51, 60, 237  
   radiative, 237  
 Chamberlain, J. W., 303  
 Chan, K. L., 130  
  
 Chandrasekhar, S., 87, 92, 218, 266, 318  
 Chapman–Enskog method, 265  
 Chapman–Jouget process, 307  
 characteristic  
    $C_-$ , 27, 307  
    $C_+$ , 27, 32, 307  
    $C_0$ , 27  
   equation of, 25  
 characteristics, 24–29, 115, 276  
   fan of, 28  
   long, 274  
   method of, 24  
   short, 274  
 charge, separation of, 31  
 Chebyshev series, 65  
 Christy, R. F., 237, 240  
 chromosphere, 188  
 circulation, of velocity, 16  
 clouds, molecular, 65  
 coarse graining, 74, 212  
 coherence, quantum state, 182  
 Colella, P., 41, 54–56, 60, 65  
 Colgate, S. A., 237  
 collision  
   electron, 175  
   electron–ion, 213  
 collocation, 65  
 combustion front, 306, 307  
 commutator relation, 155, 164, 169  
 complete linearization method, 192, 193  
 complete redistribution, 188, 195, 196, 198–200, 204,  
   207, 209, 211  
 compression ratio, ionization front, 305  
 Compton effect, 160  
 Compton reflection, inverse, 318  
 Condon, E. U., 152  
 conduction  
   heat, 12–14, 299, 300, 320  
   artificial, 56  
 conductivity, thermal, 14, 23, 300  
 configuration interaction, 168, 176  
 confluent hypergeometric equation, 316  
 confluent hypergeometric functions, 316  
 conservation equations, 30  
 conservation laws, 56, 57, 300  
   material plus radiation, 85  
 conservation-law form, 52  
 constraint  
   time-step, 237  
   radiation diffusion, 237  
 contact discontinuity, 38, 54, 55  
   smearing, 40  
 continua, photoionization, 272  
 continuity equation, 30  
 continuous medium picture, 212  
 Cook, J. D., 211  
 cooling  
   Newton's, 21, 139  
   time constant, 22, 141, 292  
   minimum, 141  
 Cooper, G., 312

- Cooper, J., 196
- coordinates
  - angle, 70, 75
  - curvilinear, 78
  - spherical, 268
- coronal hole, 303
- corrections, velocity, 108
- correlation
  - function, two-particle, 213
  - plasma, 214
- Courant condition, *see* CFL condition
- Courant, R., 24, 28, 29, 44, 307
- Cowie, L. L., 299
- Cox, A. N., 176
- Cox, J. P., 69, 80, 158, 212, 215–217, 237
- CRD, *see* complete redistribution
- cross section
  - absorption
    - line, 157, 158, 190
  - differential, 160, 162, 163, 169, 309
  - moments of, 311
  - Klein–Nishina, 161, 291, 311
  - photoionization, 164
  - radiative capture, 165
  - scattering, 159
  - Thomson, 160, 161
- Cummings, J. D., 291
- curve-of-growth function, 208
- de-excitation, collisional, 181
- Debye length, 171
- deflagration, 307
- degeneracy, electron, 166
- density matrix, atomic, 230
- density, electron, 184
- departure coefficient, from LTE, 189
- detonation, 307
- dielectric constant, 212
  - complex, 213
- dielectric tensor, 226, 229
- differencing, conservative, 277
- differential equation
  - regular singular point, 329
  - singular locus, 329
  - singular point, 328
    - regularity, 329
  - stiff, 181, 239
- diffusion
  - 1-D, 245
  - approximation, 245
  - double, 200
  - equilibrium, 240–241, 258, 259
  - finite-difference
    - 2-D, 245
  - flux-limited, 264–266
  - frequency, 130, 198
  - multidimensional, 245
  - nonlinear, 258, 265
  - second order, 119
  - thermal, 240–241, 243, 245, 294, 295, 298, 304, 323, 324
    - validity, 298
- diffusion approximation, 80–84, 172, 217, 237, 240, 248, 253, 257, 258, 265
  - comoving frame, 117–122
  - distinct from Eddington, 83
  - explicit differencing, 238
  - pressure tensor, 83
    - with velocity gradient, 133
- diffusion coefficient, 264
- diffusion region, 108
- dimensional analysis, 35
- dipole approximation, 164
- dipoles, oscillating, 214
- direct Eulerian method, 54, 55
- direct numerical simulation (DNS), 65
- direction cosine, 283
- direction vector, radiation, 75
- discrete ordinates, method of, 95, 266–268
- dispersion
  - plasma, 214
- dispersion function, 21, 231
- dispersion relation, 17, 19, 21, 22, 145, 294
  - VEF equation, 261
- dissipation
  - viscous, 13, 14
- dissipation function, 14
- dissipative, numerical method, 238
- distribution function, phase space, 69
- distribution, Poisson, 132, 136
- domain of dependence, 25
- Doppler effect, 79, 102–104, 112, 114, 123, 161, 291
- Doppler width, 184, 231
- Dreizler, S., 290
- duality, wave-particle, 74
- Dykema, P. G., 189, 192, 260, 278
- DYNA3D code, 62
- dynamics
  - gas, 5–40
  - structural, 62
  - vortex, 16
- $E_n(x)$ , 90–92, 96, 266, 287, 289
- Eastman, R. G., 133–135, 291
- Eddington approximation, 83, 91–93, 97, 199, 242–245, 260, 263–265, 294, 323, 324
- Eddington factor, 94, 245, 263, 264, 270
- Eddington limit, 147
- Eddington luminosity, 147
- Eddington tensor, 260, 262, 277, 282
- Eddington, A. S., 139
- Eddington–Barbier relation, 99–101, 187
- eigenvectors, generalized, 25
- Einstein coefficient, 154–158, 165
  - $A_{ba}$ , 155, 191
  - $B_{ab}$ , 156
  - $B_{ba}$ , 155
- electric field, 31
- electron, free, 213
  - electron spin, 164
- element mixture
  - astrophysical, 174

- emission, 76, 153–158
  - microwave, 226
  - spontaneous, 181, 230
  - stimulated, 77, 172, 181, 191, 206, 214, 226, 230, 309
  - thermal, 220, 224, 282
- emission coefficient, 77
- emissivity, 75–78, 86, 89, 102, 158, 174, 182, 204, 309
  - anisotropic, 79
  - effective, 292
  - invariant, 106
  - refractive, 216
  - Stokes vector, 224, 225, 227
- energy
  - relativistic, 103
  - uncertainty, 196
- energy coupling
  - radiation–matter, 85, 173, 308
  - implicit, 286, 290, 291
- energy density
  - radiation, 71, 72, 107, 138, 215
  - comoving frame, 119
  - Monte Carlo estimate, 291
  - refractive, 216
  - spectral, 72
  - total, 72
- energy equation
  - combined, 241
  - linearized, 22, 291
  - radiation, 272
- ENO, 57, 59, 67
- equilibrium
  - collisional–radiative, 260
  - hydrostatic, 192
  - radiative, 192
  - statistical, 180, 189
- equivalent two-level atom (ETLA) method, 189, 192, 260
- error
  - amplification factor, 250, 255, 288
  - mode
    - short-wavelength, 254
  - truncation, 238
- error function, complex, 232
- escape factor, 191
- escape probability, 91, 204
  - angle-dependent, 126
  - approximation, 91, 126, 191, 272–274
  - second-order, 273, 274
  - single-flight, 204, 260, 272
    - as approximate lambda operator, 289
  - two-sided, 91, 186, 205, 272, 273
- Sobolev, 126
- Euler equations, 6–8, 49, 61
  - first, 7
  - linearized, 20, 142
  - second, 7
  - third, 8
- Eulerian method, 26, 49–61, 67, 276
- Eulerian picture, 6
- evaporation, of interstellar cloud, 299–303
- evaporation rate, 303
- evaporation front, 299
- excitation, collisional, 181
- excited-state population, Monte Carlo estimate, 292
- exothermic, combustion front, 307
- expansion opacity, 130–137
  - iron spectrum, 135
  - monochromatic, 131
  - Rosseland mean, 131, 132, 134
  - s* parameter, 130
- expansion, asymptotic, 81
- exponential-integral function, *see*  $E_n(x)$
- Faraday depolarization, 235
- Faraday rotation, 226, 228, 229, 235
- Feautrier equation, 98–99, 192, 193, 205, 271, 276, 277
  - Hermite differencing, 276
- Fermi function, 167
- Fermi's Golden Rule, 154, 159
- FFT, 66
- Fick's law, 114, 117, 244
- field
  - electromagnetic, 152
  - macroscopic, 214
  - quantization, 152, 214
- finite difference method, 49–51
- finite element method, 275, 278
  - discontinuous, 275
  - bilinear (BLD), 278, 280
  - linear, 278, 279
- mass lumping, 279
- second order accurate, 279
- finite volume method, 49, 52, 279
- FLASH code, 62
- Fleck, J. A., Jr., 291
- flow
  - high Mach number, 126
  - inviscid, 29
  - irrotational, 15, 17
  - isentropic, 27
  - isothermal, 328
  - potential, 15, 17
  - self-similar, 35, 38
  - steady, 300
  - supersonic, 123
  - transonic, 299, 301
- fluid approximation, 6, 31
- flux
  - conserved, 52
  - diffusion, 83
  - emergent, 100, 187, 188
  - enthalpy, 114
  - fluid frame, 114
  - frequency-integrated, 120
  - kinetic energy, 320
  - radiation enthalpy, 138
  - vector, 72, 107
- flux divergence coefficient, 191
- flux limit, lack of, 84

- flux limiter, 84, 264–266
  - Levermore, 265
  - max, 265
  - sum, 265
- Fokker–Planck method, 197, 311
- force
  - drag, 213
  - ponderomotive, 217
- formal solution, 271
- four-momentum, 103, 104
- four-vector, 103, 105
- four-velocity, 103
- Fourier coefficients, 219
- Fourier series, 65
- Fourier space, 66
- Fourier transform, 95, 200, 210
- Fourier's law, 14
- Fraser, A. R., 102
- free energy, Gibbs, 166
- Freeman, B. E., 260
- frequencies, radio, 218
- frequency
  - Brunt–Väisälä, 147, 149
  - cyclotron, electron, 229, 230
  - electron–ion collision, 213, 229, 326
  - radiation, 70
- frequency width
  - characteristic, in PRD, 201
- Friedrichs, K. O., 24, 28, 29, 44, 59, 307
- Friend, D. B., 132, 134, 135
- Frisch, H., 197, 273
- Frisch, U., 273
- FronTier code, 67
- $\gamma$ 
  - effective, 22
  - relativistic, 103
- Galerkin method, 65, 278
- gas
  - ideal, 26, 33, 320
  - ideal Fermi, 166
- gaunt factor
  - bound–free, 167
  - free–free, 170, 183
  - radio frequency, 170
- geometry
  - Riemannian, 78
  - slab, 41, 98, 188, 204, 266, 274, 295
  - spherical, 239, 262, 268–272, 274, 276, 280
- Germaschewski, K., 60
- Gingold, R. A., 63
- Gittings, M. L., 61
- Giuli, R. T., 69, 80, 158, 212, 215–217
- Glaz, H. M., 54, 60
- Godunov method, 52–56, 61, 67
- Godunov, S. K., 24, 57
- Gol'din, V. Ya., 260
- Grauer, R., 60
- gravity, self, 64
- Great Red Spot, 16
- Green's function, 143, 144
- Greenough, J. A., 61, 68
- H and K lines, of Ca II, 188, 192
- h and k lines, of Mg II, 188
- H II region, 308
- $H_V$ , 73
- $H$ -function, Chandrasekhar, 95, 100, 268, 318
- Hamann, W.-R., 288
- Hamiltonian, 152
- Hammer, J. H., 299
- Hanbury Brown, R., 220
- Harrington, J. P., 197, 199–203
- Hauschildt, P. H., 289
- Hearn, A. G., 151
- heat of reaction, 307
- heating rate, matter, 85
- Heitler, W., 196
- Helmholtz equation, 143
- Henson, V. E., 253
- Hermiticity, 220
- Hernquist, L., 63, 64
- Hestenes, M. R., 249
- Holstein, T., 209, 211
- Hopf function, 92–94, 244, 266, 268, 285
- Howell, L. H., 61
- Huard, S., 221
- Hubeny, I., 289, 290
- Huebner, W. F., 178
- Hugoniot curve, 33
- Hummer, D. G., 124, 126, 186, 196, 201, 202, 205, 272, 289, 290
- Hurwitz–Routh criterion, 150
- Husfeld, D., 288
- hydrodynamics
  - 1-D, 41–45
  - 2-D, 45–62, 276
  - 3-D, 62
  - numerical, 40–68
- Hyman, J. M., 259
- Iglesias, C. A., 177
- impact parameter, 269, 281
- impacts, asteroid, 65
- indicial equation, 316
- infinite medium, 200
- instability
  - absolute, 144, 145, 147, 151
  - convective, 144, 147
  - global, 144
  - Kelvin–Helmholtz, 17, 19, 67
    - growth rate, 19
  - pulsation, 139
  - Rayleigh–Taylor, 17, 19, 59, 67
    - growth rate, 19
  - Richtmyer–Meshkov, 62, 67
- instability, numerical, 241
- intensity, 69–74
  - emergent, 99, 100
  - frequency-integrated, 72
  - Lorentz invariant, 106

- mean, 205, 266
- negative, 277
- steady-state, 207
- total, 218
- $x$  component, 218
- $y$  component, 218
- interior solution, 91
- internal energy equation, 42, 43, 46, 114, 240, 242, 272, 286, 290
  - Eulerian, 8
  - Lagrangian, 7, 9
- interpolation
  - monotonic, 50
  - parabolic, 277
  - piecewise-parabolic, 55
  - subzone, 50
  - van Leer, 51, 54, 55
- interstellar medium, 299
- invariant momentum volume element, 105
- invariant phase-space volume element, 105
- invariant spatial volume element, 105
- ion, hydrogen-like, 168
- ionization, 31
  - collisional, 326
- ionization front, 24, 304–308
  - D-critical, 306
  - D-type, 307
  - D-type conditions, 306
  - M-type conditions, 306
  - R-critical, 306
  - R-type, 307
  - R-type conditions, 306
  - strong, 306
  - subsonic, 306
  - supersonic, 306
  - weak, 306
- ionosphere, 226
- Irons's theorem, 204–205, 272
- iteration, source, 282
- Ivanov's approximation, 188, 274
- Ivanov, V. V., 96, 179, 188, 194, 202–204, 267
- $\bar{J}$ , 185, 200, 273, 274, 289
- $J_v$ , 73
- Jefferies, J. T., 192, 228
- Jiang, G. S., 41
- Jones, J. E., 259
- $K_1(\tau)$ , 92, 95, 185, 267, 273
  - asymptotic, 210
- $K_2(\tau)$ , 185, 188, 202, 205, 272, 273
- $K_v$ , 73
- $\tilde{K}_1(k)$ , 210
- Kahn, F. D., 304
- Kalkofen, W., 236, 288
- Kamm, J. R., 68
- Karp, A. H., 130, 135
- Katz, N., 63, 64
- Keller, G., 175, 178
- Kelvin–Helmholtz instability, *see* instability, Kelvin–Helmholtz
- kernel approximation method, 267
- kernel function, 185
  - SPH, 63
- Kershaw, D. S., 257
- kinematics, relativistic, 103, 291
- kinetic equations, 179–181, 189, 192–194, 206, 253, 272, 289
- Klein, R. I., 61, 189, 192, 260, 278, 327, 329
- Knoll, D. A., 259
- Kompaneets equation, 154
- Kompaneets, A. S., 312
- Kopp, H. J., 282
- Kourganoff, V., 87, 92, 99, 287
- Kramers law, 167
- Kramers–Kronig relation, 231
- KULL code, 62
- Kunasz, P. B., 276, 277, 289
- Kurucz, R. L., 135
- L'Hospital's rule, 301
- Lagrange plus remap, 49–51, 54, 55
- Lagrange step, 49, 51, 55
- Lagrangian method, 9–10, 29, 40–48, 51, 63, 66, 67, 240
- Lagrangian picture, 6
- Lamb, H., 141
- lambda iteration, 282, 287
- lambda operator, 287
  - approximate, 288–290
  - diagonal, 289
  - lagging, 290
  - tri-diagonal, 289
- Lanczos, C., 249, 252
- Landau, L. D., 5, 35, 36, 215, 307
- Landi Degl'Innocenti, E., 226, 230, 231, 235
- Landi Degl'Innocenti, M., 226
- Lanz, T., 290
- Laplace transform, 142, 207, 315
  - inverse, 143, 208, 209
- Larsen, E. W., 292, 294
- laser targets, 206
- Lasher, G., 130
- latent heat, of ionization, 305
- Lathrop, K. D., 284
- Lax, P. D., 56, 59
- Lax–Friedrichs method, 59
- Lax–Wendroff method, 56
  - two-step, 56, 57
- Lenoir, W. B., 226, 231
- Levermore, C. D., 265
- Lewis, E. E., 281, 282
- Lewy, H., 44
- Liepmann, H. W., 29
- lifetime
  - electron collision, 180
  - radiative, 180
  - recombination, 180
  - spontaneous, 205, 206, 209
- Lifshitz, E. M., 5, 35, 36, 215, 307
- Lightman, A. P., 311, 318
- Lindquist, R. W., 106, 107

- line broadening, 175
  - Doppler, 125, 175, 185, 187, 195, 196, 199, 200, 202, 203, 210
  - electron impact, 175, 177, 180, 196
  - ion, quasistatic, 175, 177
  - natural, 196
- line profile function, 125, 158, 184, 187, 190, 191
  - complex, 230
  - Lorentzian, 175, 187, 196, 202, 203, 210
  - Voigt, 202, 203, 209, 210, 231
- line profile, Stokes, 233
- line strength, 155
- line width, 124
- linear equations
  - Gaussian elimination, 193, 239, 246
  - incomplete Cholesky factorization, 257
  - incomplete LU factorization
    - with thresholding (ILUT), 257
  - incomplete LU factorization (ILU), 256
  - iterative solution, 241, 245–260, 287
    - alternating-direction implicit (ADI), 248–250, 257
    - biconjugate gradient (BCG), 250–253
    - block Jacobi, 248
    - Chebyshev, 246, 250–253, 259
    - conjugate gradient, 246, 249–250, 252, 254–256
    - convergence rate, 248–250
    - convergent, 256
    - Gauss–Seidel, 246–248, 257
    - generalized conjugate residual (GCR), 251
    - generalized minimum residual (GMRES), 246, 250–253, 257, 259
    - ILU-GMRES, 257
    - ILUT-GMRES, 257
    - incomplete Cholesky conjugate gradient (ICCG), 257
    - iteration count, 254
    - Jacobi, 246–248, 256
    - Krylov subspace methods, 249, 252, 259
    - multigrid, 246, 253–254, 257, 259
    - Ng, 250–253, 260, 290
    - nonsymmetric, 250, 260
    - ORTHOMIN, 246, 250–253
    - preconditioned, 255
    - preconditioned conjugate gradient, 246, 257
    - relaxation, 254, 255
    - semi-coarsening multigrid (SMG), 254, 259
    - SOR overrelaxation parameter, 248
    - successive overrelaxation (SOR), 246–248, 250, 257
    - preconditioning, 249, 255, 259, 282, 286, 288
    - sparse, 243, 246
      - fill-in, 256, 257
  - linearization, opacity, 241, 242
  - local thermodynamic equilibrium, *see* LTE
  - Loeser, R., 191
  - longest-single-flight picture, 185, 209
  - Lorentz invariant, 104, 105
  - Lorentz transformation, 103
    - absorption and emission, 106
    - energy density, 108
    - flux, 108
    - intensity, 106
    - pressure tensor, 108
    - radiation, 104–107
    - radiation moments, 107–110
  - Los Alamos Opacity Library, 178
  - LTE, 88, 172, 179, 182, 235, 304
  - Lucy, L. B., 63
  - Lyman lines, 192
  - Mach number, 34, 40, 65, 305, 306
    - isothermal, 327
  - magnetic field, 234, 235
    - transverse, 235
  - magnetometer, 235
  - Manteuffel, T. A., 252, 259
  - mapping, bilinear, 46
  - Marshak, R. E., 294
  - Marshak wave, 294–299, 304
    - analytic, 294
    - asymptotic, 294, 299
    - subsonic, 299
    - temperature distribution, 296
  - Martin, W. R., 292
  - mass density, relativistic, 109
  - mass shell, 104
  - mass, rest, 103
  - matching, velocity, 18
  - material, opaque, 74
  - matrix
    - absorption, 227
    - coherency, 219, 226, 227
    - condition number, 250, 255
    - density, 219, 220, 224
      - radiation, 220
    - eigenvalues, 247
    - emission
      - spontaneous, 231
      - stimulated, 231
    - G, 226–228, 230, 233
    - Hermitian, 219
    - Hermitian adjoint, 226
    - ill-conditioned, 255
    - Jacobian, 24, 246, 258, 260, 286
    - K, 227, 228, 230, 233
    - lower-triangular, 247
    - Mueller, 222
    - orthogonalization
      - Gram–Schmidt, 250
      - Householder, 250
    - principal minors, 150
    - prolongation, 253
    - rank-1, 290
    - restriction, 253
    - symmetric positive-definite, 241, 249, 254, 257
    - upper-triangular, 247
  - matrix element, quantum mechanical, 155
  - matter, interstellar, 230
  - Maxwell equations, 226
  - Maxwellian distribution, 182
  - McClymont, A. N., 274

- McKee, C. F., 299  
 mean free path, 31, 80  
   line scattering, 185  
   Rosseland, 297  
 mechanical energy equation, 8  
 mechanics, Newtonian, 102  
 medium  
   anisotropic, 225  
   dispersive, 215  
   infinite, 92, 207  
   interstellar, 226  
 Meijerink, J. A., 257  
 Mercier, B., 292  
 mesh  
   3-D  
     hexahedral, 279  
     tetrahedral, 279  
   AMR, 60  
   coarsening, 253  
     recursive, 253  
   corner, of cell, 279  
   distorted, 283  
   dynamic, 48  
   hexahedral, 62  
   hierarchical, 60  
   level 1, 60  
   level 2, 60  
   logical, 46  
   quadrilateral, 279  
   staggered, 41–48, 51, 61, 67  
   sweeping, 276, 277  
   transport, 276  
   unstructured, 48, 62  
 Messiah, A., 152, 158  
 Mészáros, P., 226  
 metric, Minkowski, 105  
 Meyerott, R. E., 175, 178  
 Mihalas, B. W., 2, 5, 20, 21, 69, 84, 102, 104, 109,  
   110, 118, 119, 121, 139, 268, 276, 294, 304,  
   320  
 Mihalas, D., 2, 5, 20, 21, 69, 84, 102, 104, 109, 110,  
   118, 119, 121, 139, 179, 192–194, 245, 268,  
   276, 294, 304, 320  
 Miller, W. F., Jr., 281, 282  
 Milne equation, 91–93  
   first, 92–94, 266  
   second, 95–97, 183, 186, 194, 199, 273, 287  
 Milne problem, resolvent function, 95–97, 100  
 Milne relation, 165, 167  
 Milne–Eddington model, 233  
 mode  
   acoustic, 22  
   cooling, 22, 139  
   isobaric, 23  
   isochoric, 23  
 moment equations, 78–80, 83, 90, 264, 282  
   closure, 78  
   combined, 84, 241, 242  
   comoving frame, 112, 117  
     frequency-dependent, 112  
     frequency-integrated, 113  
     fixed frame, 109  
     frequency integrated, 79  
     simplified comoving frame  
       frequency-dependent, 113, 260  
       frequency-integrated, 113  
     spherical, 269, 270  
 moments, *see* radiation, moments  
 momentum density  
   radiation, 84  
   relativistic, 109  
 momentum equation, 30, 43  
   Lagrangian, 9  
 momentum, material, 85  
 Monaghan, J. J., 63, 65  
 monotonicity, 55  
 Monte Carlo method, 63, 291–293, 319  
   cost, 292  
 Montry, G. R., 282  
 Morel, J. E., 282  
 Morton, K. W., 41, 280  
 multifrequencygray method, 290  
 multiphase  
 MUSCL, 54–56  
  
 Nagel, W., 226  
 Navier–Stokes equation, 13, 29, 65  
   incompressible, 65  
 Net Radiative Bracket, 191, 192, 204, 205, 253, 260,  
   272  
 Newton–Krylov method, 193, 246, 258–260, 290  
 Newton–Raphson method, 193, 238, 240–242, 246,  
   258, 259, 290  
   convergence, 239  
   convergence, robust, 239  
 Ng, K. C., 251  
 Noble, L. M., 303  
 Noh problem, 67  
 noise, electric field, 220  
 non-LTE, 124, 126, 133, 156, 179–194, 235, 260, 286,  
   289, 292, 304  
   multilevel atom, 188–194  
   problem, 181  
 normal vector, surface, 104  
 Norman, M. L., 41, 276  
 Nowak, P. F., 283  
 number conservation, 193  
 number of scatterings, distribution, 313, 318  
  
 $\omega_B$ , 229, 230  
 $\omega_{pe}$ , 213, 217, 218, 229, 230  
 occupation number, 153, 154  
 octant, for angle quadrature, 284  
 Olson, G. L., 251, 259, 288, 289, 295  
 Omont, A., 196  
 opacity, 172, 173  
   astrophysical, 175  
   calculation of, 172–178  
   continuous, 130, 204, 207  
   effective, 134, 135  
   flux mean, 147  
   frequency-dependent, 326



- opacity *cont.*
  - gray, 92, 93, 287
  - lagging, 241
  - Planck mean, 140, 173, 174
  - Rosseland mean, 136, 173, 174, 176, 217, 218, 242, 294, 295, 326
- Opacity Project, 176, 177
- OPAL, 176, 177
- operator
  - annihilation, 153, 215
  - creation, 153, 215
  - diffusion, 282
  - finite-difference, 253
  - Kompaneets, 313
  - projection, 59, 66
- operator splitting, 49, 54, 236–240, 242, 248, 286
  - directional, 51, 54, 55
- optical depth, 76, 87, 184, 188, 198, 199, 201, 238, 273
  - Sobolev, 125, 328
- optically thick region, 322
- optically thin regions, 241, 245
- optics, geometrical, 74
- oscillator strength, 157, 190
  - emission, 157
  - sum rule, 157
- $(p, z)$  coordinates, 270, 274, 276
- Panofsky, W., 107
- parallel displacement, 78
- parametric-potential method, 176
- Parker, E. N., 303, 329
- partial differential equation
  - conservative form, 275, 281
  - elliptic, 253
  - hyperbolic, 24
  - self-adjoint, 260
- partial redistribution, 182, 194–203, 207, 209, 211, 309
  - angle dependent, 292
  - asymptotic, 199–201
- particles, Monte Carlo, 291
- partitioning, of matrix, 193
  - Rybicki, 193, 194, 276
- path length
  - mean, 201–204
- Payne, M. G., 211
- permeability, magnetic, 226
- permittivity, electric, 226
- perturbation, surface, 17
- phase function, 160, 162, 284
- Philips, M., 107
- photoexcitation, 181
- photoionization, 163–168, 172, 190, 295
- photon
  - boson statistics, 220
  - conservation of, 312
  - dressed, 214
  - four-momentum, 103
  - mean frequency
    - Compton boost, 313
  - momentum, 72
  - number density, 72, 312
  - phase-space density, 72, 104, 309
- photosphere, 184, 188, 206, 263
- Picard iteration, 258, 259
- Pinto, P. A., 133–135, 291
- Planck function, 81, 88, 119, 124, 156, 310
- Planck mean, 136
- plane, tangent, 276
- plasma
  - dense, 214
  - frequency, electron, 172, 213, 214, 217, 218, 229, 230
  - magnetized, 79, 225
  - interstellar, 229
  - microfield, 175
- PLMDE, 55, 61, 67, 68
- Poincaré sphere, 221, 228
- Poisson equation, 66, 262
- Poisson process, 134
- Poisson statistics, 314
- polarizability, AC, 162
- polarization, 70
  - component,  $\sigma$ , 235
  - mode, 164, 219, 220
    - left-circular, 223
    - orthogonal, 221, 228
    - right-circular, 223
  - rotation, 226
- plane of, 221
  - rotation, 230
- polarized light, 160, 218–235
  - anisotropic media, 225–235
  - basis, 222, 227
  - birefringent media, 225–235
  - circular, 221, 235
  - compensator, 222
  - component, 228
  - elliptical, 220, 221
  - ellipticity, 221
  - left-circular, 221
  - linear, 221, 225, 235
  - mathematical description of, 218
  - phase plate, 222
  - right-circular, 221
- polarizer, 228
- polynomial
  - Chebyshev, 252
  - Legendre, 284
- Pomraning, G. C., 2, 69, 84, 86, 264, 275, 294, 295, 311
- populations, atomic level, 179, 189, 191, 200, 235
- position vector, 75
- positivity, of transfer solution, 277–279
- potential
  - chemical, 166
  - vector, 152, 215
  - velocity, 15, 17
- Poynting vector, 108
- PPM, 55, 56, 62, 67, 68
- PPMLR, 55

- Prandtl number, 14  
 PRD, *see* partial redistribution  
 pre-conditioning, 193  
 processes  
   nonlinear, 77  
   stochastic, 220  
 PROMETHEUS code, 67  
 protostar, 238  
 pseudo-spectral method, 65  
 pseudo-viscosity, 43, 48, 51, 56  
   centering, 48  
   linear, 45  
   monotonic, 45, 51  
 Puetter, R. C., 191, 274  
 pulsar, 226  
   dispersion measure, 230  
 QED, 152–154, 226  
 quadrature  
   angle, 266, 282  
   adaptive, 285  
   Gaussian, 266  
 quarter-wave plate, 218, 221, 222  
 quasar, broad emission lines, 274  
 quasi-Newton method, 290  
 quenching, 183, 191, 202, 209  
  
 $R_I(x, x')$ , 196, 197  
 $R_{II}(x, x')$ , 196–198, 202, 203  
 $R_{III}(x, x')$ , 196  
 $R_{IV}(x, x')$ , 196, 197  
 Rachkovsky, D. N., 226  
 radiation  
   angle moments, 72, 79, 82  
   body force due to, 126, 129, 147, 327  
   comoving frame, 242, 291  
   Comptonization of, 308–319  
   energy advection term, 242  
   energy, conservation of, 79, 277  
   enthalpy, 139  
   entropy, 139  
   field, symmetries, 284  
    $\gamma$ , 139  
    $\gamma = 4/3$  ideal gas, 74  
   imprisoned, 138–139  
   incident, 243  
   isotropic, 74  
   moments, 69–74, 90, 107, 271  
   momentum, 79, 80, 217  
   line, 327  
   pressure, 138  
   isotropic, 83  
   refractive, 216  
   pressure tensor  
     monochromatic, 121  
   quantized, 220  
   response to fluctuations, 140  
   transfer  
     astrophysical, 98  
     slab geometry, 87–91  
     steady-state, 86–101  
   work term, 242  
 radiation transport  
   comoving frame, 102–137  
   numerical, 236–293  
   spectral line, 123  
 radiation–matter coupling, 84–85, 114, 140  
   comoving frame, 109  
   fluid frame, 109  
   four-vector, 109  
   stationary frame, 109  
 radiative acceleration, 328  
    $\alpha$ -power law, 328  
 radiative transfer  
   LTE, 226  
   probabilistic, 273  
   spherical symmetry, 268–272  
 radiative transitions, net rate, 156, 191, 289  
 RAGE code, 61, 67  
 Raizer, Yu. P., 3, 35, 294, 307, 320  
 Ramoné, G. L., 283  
 random walk, 130, 185  
 Rankine–Hugoniot relations, 29–35, 322  
 Rasio, F. A., 63  
 rate  
   electron collision, 182, 189  
   inelastic, 180  
   photoabsorption, 180, 189, 205  
   radiative, 180, 189  
     effective, 289  
   radiative decay, 190  
     spontaneous, 180  
     stimulated, 180  
 rate coefficient, 180, 189  
 rate matrix, eigenvalue, 181  
 ray effect, 283, 285  
 Rayleigh–Jeans approximation, 226  
 Rayleigh–Taylor instability, *see* instability, Rayleigh–Taylor  
 rays, curved, 215, 276  
 reciprocity relation, 165, 169  
 recombination  
   coefficient, 167  
   radiative, 31, 163–168, 326  
   rate, 167  
   spontaneous, 167  
 recursion, stable, 245  
 redistribution function, 195  
   Compton, 308  
   symmetry, 309, 310  
   symmetric, 195  
 Reed, W. H., 282  
 Rees, D. E., 223, 233  
 reflectance, diffuse, 318  
 reflection, diffuse, 318  
 refraction, 212–218  
   index of, 212, 213, 217  
   tensor index of, complex, 226  
 region of influence, 55  
 remap step, 55

- residual, preconditioned, 255
- resonance fluorescence, 182
- Reynolds number, 121
- Richardson extrapolation, 61
- Richtmyer, R. D., 41, 43, 56, 280
- Rider, W. J., 68, 259
- Riemann invariant, 27, 28
- Riemann problem, 52, 56
  - general, 53
- ringing, at discontinuity, 40, 57
- RK3, 57, 59
- rocket effect, 303
- Rogers, F. J., 177
- Rosen, M. D., 299
- Roshko, A., 29
- rotation measure, 230
- Runge–Kutta method, 57, 66
- Rybicki, G. B., 124, 126, 193, 204, 205, 273, 288–290, 311, 318
- $S_N$  method, 270, 274–286, 289, 292
  - angle sets, 283–286
    - for 2-D and 3-D, 285–286
    - level symmetric, 284
    - Set A, 283
    - Set B, 283
  - corner balance, 275, 280
    - corner intensity, 279, 280
    - nonlinear, 278
    - simple (SCB), 279, 280
    - upstream (UCB), 278, 280
  - diamond difference, 275, 280–282
  - diffusion synthetic acceleration, 282, 290
  - step difference, 275, 280–282
  - transport synthetic acceleration, 282, 283
  - weighted diamond difference, 282
- Saad, Y., 246, 248, 252, 256, 257, 259
- Saha equation, 166, 167
- Salpeter, E. E., 130
- Sampson, D. H., 179
- Scarf, F. L., 303
- scattering, 77, 88, 89, 153, 154, 158–163, 282
  - Compton, 89, 291, 308
    - bias, 310
    - inverse, 316, 318
    - Kompaneets equation, 312, 313, 316, 318
    - $y$  parameter, 313, 316
  - conservative, 92, 100, 195, 202
  - effective, 282, 292
  - electron, 89, 295, 308
  - generating function, 313, 315, 318
  - isotropic, 78
  - line, 183
  - mean number of, 201–205, 287, 313, 314
  - polarized, 224
  - Raman, 162
  - Rayleigh, 162, 172, 182, 183, 214, 224
  - redistribution function, 78
  - resonance line, 124, 195
  - stimulated, 78, 154, 160, 172, 309, 313
  - Thomson, 158, 172, 183, 185, 214, 224, 308, 328
  - Scharmer, G. B., 288
  - Schwarzschild, M., 80
  - searchlight problem, 277
  - Seaton, M. J., 176, 177
  - Sedov, L. I., 35–37
  - Shi, J., 59
  - shock tube, 37–40, 52
  - shock wave, 28–35, 37, 51, 52, 307
    - adiabatic, 327
    - cooling region, 324, 326
    - entropy jump, 34, 42
    - internal energy jump, 33
    - internal structure of, 31
    - isothermal, 326
    - jump conditions, 31, 38, 305
      - isothermal, 326
    - postshock cooling, 323
    - postshock cooling, 326
    - precursor heating, 323
    - precursor region, 323, 324, 326
    - radiating, 319–327
      - diagnostic diagram, 320
      - supercritical, 322
    - release, 53
    - spreading, 43
    - strong, 34
    - structure, radiating, 323
    - temperature spike, 325
    - thickness of, 31
    - velocity jump, 33, 51, 57
  - shock-within-a-shock, 322
  - Shortley, G. H., 152
  - Shu, C. W., 41, 59
  - similarity solution, 35
  - Smith, E. W., 196
  - smoothed particle hydrodynamics, *see* SPH
  - Sobel'man, I. I., 152, 158, 163, 179
  - Sobolev, V. V., 95, 96, 122, 188
  - Sobolev approximation, 122–130, 135, 272, 327
    - diffusion correction, 127
    - finite cone-angle, 331
    - radial beaming, 129, 331
  - Sobolev equation, 124
  - Sobolev escape probability, 127, 130
    - approximate, 128
  - Sobolev optical depth, 127, 130, 135
  - Sod, G. A., 57
  - Sod shock tube, 57, 59, 65, 68
  - solar atmosphere, 233
  - solar corona, 161, 218, 285, 303
  - solar flare, 285
  - solar photosphere, magnetized, 226
  - solar spectrum, 188
  - solid angle, 75
  - sound speed
    - barotropic, 21
    - isothermal, 300, 305, 328
  - source function, 88, 95, 96, 156, 165, 183, 184, 186–191, 205, 210, 266, 268, 273, 274, 276, 277, 282
    - angle-dependent, 99

- frequency-independent, 182
- line, 124, 182
- scattering, 89
- Stokes vector, 227
- total, 89
- spectral distribution, Comptonized, 313–315
- spectral lines
  - cyclotron, 226
  - frequency distribution, 130
  - stochastic, 132, 134
  - narrow, 190–192
  - resonance, 196, 198, 206
  - subordinate, 198
  - transport, 179–211
    - infinite medium, 209
    - time-dependent, 205–211
  - trapping, 209
  - wings, 199
- spectral method, 63–67
- spectrum, microwave, 226
- speeds
  - characteristic, 26
  - postshock, 32
  - pres shock, 32
- SPH, 63–66
- Spitzer, L., 300
- spline, 63
- stability, numerical, 237
- staggering, time, 42, 46, 240
- Stark effect, 175
- stars
  - binary, 65
  - cepheid variable, 139, 240
  - hot, 184
  - luminous, 149
  - neutron, 226
  - oscillations, 139
  - pulsation, 238, 240, 327
  - RR Lyrae, 240, 241
- states, density of, 159, 163, 165, 214
- stellar atmosphere, 308
- stellar interiors model, 138
- stellar wind, 126, 300
  - boundary conditions, 328
  - CAK model, 134, 327–332
  - equations, 328
  - hypersonic, 330
  - Parker model, 303
  - Parker radius, 328
  - radiatively-driven, 327–332
    - instability, 327, 332
    - mass-loss rate, 328, 331
    - singular point, 330
    - singular point radius, 331
    - terminal velocity, 331
    - velocity law, 331
    - x-ray emission, 327
  - sonic point, 329
- stencil
  - differencing, 58
  - upwind, 59
- Stewart, J. N., 176
- Stibbs, D. W. N., 196
- Stiefel, E. L., 249
- stimulation factor, 310
- Stokes parameters, 219, 220, 223, 228, 234
- Stokes vector, 223, 227, 230
  - additivity, 224
- Stone, J. M., 276
- strain rate, 127
- Strang splitting, 55, 239
- Strang, W. G., 55
- stress, viscous, 12
- Su, B., 295
- sunspot, 234
- super transition array (STA), 177
- supergranulation cell, 285
- supernova, 126
  - spectra, 289
- susceptibility, electric, 212, 213
- symmetry
  - axial, 276, 280, 281
  - three-fold, of angle sets, 283
- Synge, J. L., 104
- Taylor, G. I., 35–37
- temperature
  - effective, 93
  - stagnation, 322
- temperature distribution, gray atmosphere, 93
- temperature front, 294
- temperature minimum, 188
- tensor
  - divergence of
    - spherical symmetry, 269
  - pressure, 73, 74
    - radiation, 73, 107, 121
  - rate-of-strain, 12, 127, 130
  - scalar, 74, 264
  - stress, 12
    - Maxwell, 108
  - stress-energy, 107
    - electromagnetic, 107
- terrestrial problems, 206
- thermalization, 95–97
  - depth, 97, 100, 186–188, 201
  - layer, 100
  - length, 96, 97, 199, 200
- thermodynamic equilibrium, 81, 88, 119, 156
- thermodynamics, second law of, 216
- Thomas, L. H., 102
- Thomas, R. N., 191, 192
- three-volume, oriented, 104, 105
- 3*j* symbol, 232
- tidal disruption, 65
- time
  - cooling, 145
  - dwelling, 203
  - dynamical, 145
  - flow, 180

- time *cont.*
  - light-travel, 181, 207
    - for mean free path, 205, 206
    - thermalization length, 209
  - mean decay, 209
  - proper, 103
    - element of, 104
  - relativity of, 111
  - retarded, 86
  - scales in line transport, 205
- time centering, 241
- time differencing
  - Crank–Nicholson, 241
  - explicit, 237
- time-differencing, implicit, 238, 239, 241, 258, 265
- Tipton, R., 62
- TLUSTY code, 290
- total energy
  - discrete, 43
  - material, 85
- total energy equation, 8, 14, 30, 114, 286
  - matter plus radiation, 108
- track length, Monte Carlo, 291
- tracking, Monte Carlo, 291
- transfer equation, 88, 191, 226, 227, 266, 272, 274
  - 2-D, 9-point stencil, 276
  - angle derivative, 280
  - even-parity, 98
  - formal solution, 263
  - second order, 98
  - spherical
    - $(p, z)$  coordinates, 270
  - Stokes, 230
- transformations, unitary, 222
- transition
  - free–free, 170
  - two-electron, 168
- transition probability, 154
- transition region, solar, 188
- transmission, diffuse, 101
- transport equation, 75–78, 86, 207, 276, 287
  - comoving frame, 110–114, 118, 123
    - acceleration terms, 111
    - angle derivative, 124
    - boundary-value problem, 114–117
    - frequency derivative, 123
    - summary, 114
    - time derivative, 124
  - covariant, 107
  - formal solution
    - 3-D, 86–87
  - linear, 291
  - polarized light
    - anisotropic medium, 228, 230
    - isotropic medium, 223–225
  - refractive, 215
  - retardation, 263
  - spherical, 269, 275
- tree method, 64
- TREESPH code, 64
- tri-diagonal matrix, 245, 248
  - block, 193, 194, 246, 276
  - recursion method, 245
- triangle number, 283, 284
- turbulence, homogeneous, 61, 65
- TVB (total variation bounded), 57
- TVD (total variation diminishing), 57
- Twiss, R. Q., 220
- two-level atom, 181–188, 206, 207, 274
- Unno, W., 226
- update, conservative, 55, 56
- upwind difference, 275, 278
- V-cycle, 253, 254, 259
- vacuum region, 261
- van Leer, B., 41, 54
- Van Regemorter, H., 183
- variable Eddington factor, *see* VEF approximation
- variables, zone-centered, 52
- VEF approximation, 94, 260–264, 271, 290
  - conformal factor, 261
  - curl condition, 261, 262
  - integrating factor, 261, 270
  - spherical, 270
- velocity
  - edge-centered, 50
  - effective, for line transport, 210, 211
  - grid, 10
  - group, 19, 215, 216
  - lagging, 43
  - phase, 19, 21, 212, 216
- velocity distribution, electron, relativistic, 291
- Vinsome, P. K. W., 251
- viscosity, 12–14
  - bulk, radiation, 121
  - coefficient of, 13
    - bulk, 13
    - radiation, 121
- volume element, momentum space, 104
- volume, specific, 32
- von Neumann, J., 41, 43
- von Waldenfels, W., 133
- vortex sheet, 17, 19
- vorticity, 15, 16, 19, 66
  - baroclinic, 17
  - conservation, 16
- vorticity equation, 16
- wave
  - blast, 35–37
    - colliding, 68
    - density, 36
    - pressure, 36
    - velocity, 36
  - bleaching, 297
  - compression, 28
  - deep water, 17, 19
  - deflagration, 24
  - detonation, 24
  - excitation, 211

- gravity mode, 147
- mode, 21
  - longitudinal, 21
- nonadiabatic, 139–141
- radiation-coupled, 138–151
- radio, 228
- rarefaction, 28, 37, 52, 54
  - centered, 28, 38
- shock, *see* shock wave
- simple, 24–29, 40
- sinusoidal, 20
- sound, 20–24
  - adiabatic, 22
  - damping, 23, 140
  - radiation-driven, 141
- spectrum, 146
  - acoustic branch, 146
  - thermal branch, 146
- thermal, 294
  - self-similar, 294
- wave equation, 84
- wave packet, 19
- wave vector, 20, 213
- waves, spherical, 164
- Wehrse, R., 132, 133, 135
- weighted essentially Nonoscillatory, *see* WENO
- Weisskopf, V. F., 196
- Wendroff, B., 56
- WENO, 56–59, 67
- WENO5, 59, 67, 68
- WENO9, 59, 67
- Werner, K., 288, 290
- Wesseling, P., 253
- White, R. H., 237
- Whitham, G. B., 29
- Wien function, 316, 318
- Wien peak, 319
- Wien's displacement law, 118, 119
- Wiener–Hopf method, 92, 95
- Wigner–Eckart theorem, 232
- Wilson, J. R., 41, 49, 50, 61
- windows, spectral, 326
- Wolf, E., 219
- Woodward, C. S., 259
- Woodward double Mach reflection, 59
- Woodward, P. R., 41, 55, 56, 59, 65
- Wooley, R. v. d. R., 196
- work, radiation, 109
- Zeeman component,  $\sigma$ –, 233
- Zeeman effect, 79, 225, 226, 231
  - anomalous, 235
- Zeeman splitting, 231
- Zeeman triplet, normal, 231, 235
- Zel'dovich, Ya. B., 3, 35, 294, 307, 319
- ZEUS-2D code, 41, 276, 277
- Zhang, H. L., 179
- Zhang, Y. T., 59
- zone
  - area, 46
  - bowtie, 47
  - donor, 50
  - dual, 47, 51
  - logical, 46
  - phantom, 44
  - polygonal, 48
  - quadrilateral, 46