

Index

- W* screened interaction, 209
- Φ functional, 287
 - exchange-correlation part, 306
- Φ -derivable self-energy, 287, 314
 - particle–phonon systems, 499
- Ψ functional, 306
- δ function, 4, 575, 627
 - on the contour, 113, 137
 - space–spin, 5
 - space–spin–time, 119
- f -sum rule, 342, 402, 404
- addition energy, 172
- adiabatic assumption, 105, 271, 522
- advanced function, 140
- affinity, 172
- analytic continuation rules, 136
- Anderson model, 54, 149, 151, 154, 176
 - conductance, 255, 299
- annihilation operator, 19
 - algebraic interpretation, 26
- anti-time-ordered function, 142
- antiferromagnetism, 64
- approximation
 - Born–Oppenheimer, 71, 470, 511
 - conserving, 313, 375
 - Ehrenfest, 491, 498, 541
 - Fan–Migdal, 496, 512, 529
 - G_0W_0 , 327, 420, 438
 - GW, 212, 326, 399, 436, 495, 512, 528, 560, 639
 - GW + exchange, 560
 - Hartree, 358
 - Hartree plus screened exchange, 376
 - Hartree–Fock, 223, 358
 - Markovian, 544, 569
- RPA, 426
- second Born, 208, 286, 359, 364, 557, 638, 658
- T-matrix ph, 328
- T-matrix pp, 328, 387
- T-matrix pp + exchange, 328
- Tamm–Dancoff, 382
- armchair nanotubes, 50
- asymptotic expansion, 420, 613
- Baker–Campbell–Hausdorff formula, 76, 81
- band, 48
 - conduction, 48, 52
 - ferromagnetism flat, 53
 - phononic, 468
 - structure, 48, 186
 - phononic, 468, 511
 - valence, 48, 52
- BBGKY hierarchy, 619
- BCS model, 64, 389
- benzene, 37
- Bethe–Salpeter equation
 - for the reducible kernel K_r , 367
 - for the reducible kernel $K_{xc,r}$, 396, 492
 - for the two-particle XC function L , 368, 374, 376
 - for the vertex function Γ , 397
 - for the vertex function Λ , 395
 - Hartree plus screened exchange, 376
- bipartite lattice, 60
- Bloch
 - functions, 48
 - theorem, 48, 465
- Bohr frequency, 625
- Bohr magneton, 5, 59, 64, 79
- Boltzmann constant, 599

- Boltzmann equations, 552
- Born–Oppenheimer approximation, 71, 470
 - connection with phonons, 511
- Born–von Karman boundary condition, 46, 466
- Bose condensation, 160
- Bose function, 159, 269, 330, 339, 536
- bosons, 10
 - hardcore, 66
- bra, 2
- carbon nanotubes, 50
- Cauchy relation, 55, 673
- Cauchy residue theorem, 154, 673
- causality property, 165, 340
- collision integrals, 242, 530, 634
- completeness relation, 4, 8, 9, 15
 - identical particles, 15
 - one-particle, 5
 - momentum space, 6
- conductance, 299
- conduction band, 48, 52
- conservation law
 - angular momentum, 321
 - energy, 323
 - momentum, 320
- conserving approximations, 313, 315, 375, 499, 512, 531
- constant interaction model, 303
- continuity equation, 88, 316
- contour
 - Konstantinov–Perel’, 102
 - Schwinger–Keldysh, 98
- Cooper pair, 66, 390
- Coulomb blockade, 177, 302
- Coulomb gauge, 79, 453
- Coulomb integrals, 32, 40, 213
 - Hubbard model, 58
- creation operator, 17, 18
 - algebraic interpretation, 25
- cross section, 412, 658
- current density, 90
- current response function, 336
- current–density response function, 336
- Debye–Waller interaction, 462
- density
 - in terms of G , 125, 162
- density matrix
 - n -particle, 603
 - probability interpretation, 607, 608
- one-particle, 223, 265, 522
 - equation of motion, 522
- operator in Fock space, 99
- phasonic, 525
 - equation of motion, 525
- two-particle, 603
- density of states
 - Hartree–Fock, 230
 - single particle, 173
- density operator, 21, 27
- density response function, 336
 - noninteracting, 345, 422
 - RPA, 425
- diagrams
 - Φ functional, 287, 303, 326
 - density response function, 210, 303
 - Green’s function, 198
 - connected, 200
 - disconnected, 200
 - topologically equivalent, 203
 - irreducible kernel for G_2 , 365
 - phasonic self-energy, 490
 - skeleton in D , 490
 - skeleton in G , 490
 - skeleton in W , 492
 - polarization, 209
 - particle–phonon systems, 491
 - reducible kernel for G_2 , 365
 - screened interaction, 209, 492
 - self-energy, 205
 - bubble, 326
 - one-particle irreducible, 205
 - one-particle reducible, 282
 - oyster, 206
 - skeleton in D , 491
 - skeleton in G , 206, 488
 - skeleton in W , 210, 492
 - tadpole, 206, 491
 - two-particle Green’s function, 361
 - connected, 363

Index

691

- skeleton in G , 364
- skeleton in W , 364
- topologically equivalent, 363
- two-particle XC function, 367
- vacuum, 197
 - connected, 275, 278
 - topologically equivalent, 279
- diamagnetic current density, 88, 460
 - in terms of G , 316
- dielectric function, 431, 664
- discrete Fourier transform, 408
- dissociation limit, 42
- distinguishable particles, 7
- double excitations, 348
- dual space, 2
- Dyson equation
 - for the Green's function, 206, 243, 282
 - for the RPA response function, 426
 - for the screened interaction, 209, 639, 666
- effective mass, 441
 - polaron, 76
- Ehrenfest
 - approximation, 491, 498
 - response function, 541
 - self-energy, 491
- electron gas, 220, 227
 - absorption energy, 356
 - dynamical screening, 427
 - effective mass, 441
 - Hartree approximation
 - equation of state, 221
 - spectral function, 222
 - Hartree–Fock approximation
 - density of states, 230
 - quasi-particle energy, 229
 - spin-polarized solution, 230
 - total energy, 230
 - lifetime, 264
 - G_0W_0 , 441
 - second Born, 412
 - Lindhard function, 423
 - Luttinger–Ward theorem, 295
 - momentum distribution
- discontinuity, 296
- G_0W_0 , 448
- pair-correlation function, 609
- plasmon, 429, 442
 - time-dependent density, 433
- quasi-particle energy, 263, 414
 - G_0W_0 , 442, 448
 - Hartree–Fock approximation, 229
- quasi-particle renormalization factor, 264
 - G_0W_0 , 449
 - second Born, 414
- quasi-particle width, 263
 - G_0W_0 , 446
 - second Born approximation, 412
- quench dynamics, 432
- RPA response function, 426
- screening density, 435
- spectral function
 - G_0W_0 , 446
 - Hartree approximation, 222
- Thomas–Fermi screening, 427
- total energy, 416
 - asymptotic expansion, 420
 - G_0W_0 approximation, 420
 - GW approximation, 420
 - Hartree–Fock approximation, 230
- electron-hole pair, 346, 425
- embedding self-energy, 56, 249
 - WBLA, 57, 642
- energy
 - correlated part, 267
 - electron gas, 415
 - Galitskii–Migdal formula, 194
 - Hartree approximation, 219
 - Hartree–Fock approximation, 226
 - electron gas, 230, 232
- interaction
 - correlation part, 266
 - Hartree–Fock part, 265
 - in terms of Γ_2 , 603, 608
 - in terms of G and Σ , 265, 266, 289
 - in terms of G_2 , 126, 193
 - in terms of P and W , 308
- noncorrelated part, 267
- one-body part, 265

- energy gap, 50
- energy-loss function, 356
- ensemble average, 99, 334
- equation of motion
 - n -particle Green's functions, 125
 - field operators, 87
 - on the contour, III
 - for operators, 86
 - on the contour, II0
 - Green's function, 208, 235, 248, 314
 - noninteracting, 128, 148
 - operator correlators, 121
- equation(s)
 - Bethe–Salpeter, 367, 368, 374, 376, 395–397, 492
 - Boltzmann, 552
 - Dyson, 206, 209, 243, 282, 426, 639, 666
 - Gross–Pitaevskii, 218
 - Hartree, 217
 - Hartree–Fock, 224
 - Hedin, 398, 661
 - Hedin–Baym, 495
 - Kadanoff–Baym, 241, 246, 499
 - Lindblad, 570
 - Liouville–von Neumann, 566
 - Lippmann–Schwinger, 387, 656
 - Maxwell, 451
 - Maxwell–Lorentz, 452
 - Poisson, 458
 - Redfield, 569
 - Schrödinger, 80
 - semiconductor Bloch, 533
 - semiconductor electron–phonon, 549
 - van der Waals, 222
- excitation amplitudes, 340, 346
- exciton, 188
 - in photoabsorption, 383
 - in photoemission, 186
 - wavefunction, 189
- excitonic Mott transition, 386
- Faddeev equation, 357
- Fan–Migdal approximation, 496, 512, 529
- Fermi energy
 - Anderson model, 54
 - electron gas, 228
 - noninteracting Green's function, 166
- Fermi function, 154, 159
- Fermi golden rule, 180, 631
- Fermi liquid, 449
- Fermi momentum, 228, 231, 296
- Fermi surface, 186
 - sharpness, 299, 449
- fermions, 10
- ferromagnetism, 53
 - flat-band, 53
- Feynman diagrams, 196
 - particle–photon systems, 486
- Feynman rules, 212
 - discrete basis, 213
 - for the bare vacuum diagrams, 197
 - for the displacement, 488
 - for the grand potential, 280
 - for the Green's function, 204
 - particle–photon systems, 486
 - for the irreducible kernel of G_2 , 366
 - for the phasonic Green's function, 488
 - for the polarization, 211
 - for the reducible kernel of G_2 , 365, 366
 - for the self-energy, 206
 - for the two-particle Green's function, 363
- field operators, 18
 - (anti)commutation relations, 21
 - general basis, 22
- first Brillouin zone, 47, 591
- first quantization, 17
- fluctuation–dissipation theorem
 - Green's function, 165, 170, 646
 - phasonic Green's function, 506, 517
 - polarization, 269
 - response function, 339
 - screened interaction, 269
 - self-energy, 258
 - T-matrix, 330
- Fock space, 17
- formula
 - Baker–Campbell–Hausdorff, 76, 81
 - Galitskii–Migdal, 194, 315
 - Kubo, 334
 - Landauer–Büttiker, 254, 648

Index 693

- Laplace, 581
- Meir-Wingreen, 252
- Stirling, 598
- Fröhlich model, 69
- free energy, 596
- Friedel oscillations, 178, 435
- Friedel sum rule, 301
- functional
 - Φ , 287
 - Ψ , 306
 - Klein, 292
 - Luttinger-Ward, 291
 - screened Luttinger-Ward, 310
- Galitskii-Migdal formula, 194
 - and conserving approximations, 315
- gauge condition, 453
- gauge transformation, 87, 452
 - field operators, 87
 - Green's function, 316
 - one-particle states, 192
 - Ward identity, 401
- Gell-Mann-Low theorem, 105
- Generalized Kadanoff-Baym Ansatz, *see* GKBA, 523
- Gibbs energy, 596
- GKBA, 523
 - fermions, 523
 - mirrored, 524
 - phosons, 526
 - mirrored, 526
- good quantum number, 157, 162, 172
- grand potential, 278, 596
 - dressed expansion in G , 288
 - dressed expansion in G and W , 310
 - expansion in G_0 and v , 279
 - from Klein functional, 292
 - from Luttinger-Ward functional, 290
- graphene, 44
- greater function, 137
- Green's function, 125
 - correlator, 119
 - dressed, 207
 - n -particle, 123
 - operator, 147
- equations of motion, 208, 235, 248, 314
 - particle-photon systems, 479
- equilibrium, 167
- exact expansion, 131
- greater, 155
- KMS relations, 159
- lesser, 155
- Matsubara, 152, 239
- noninteracting, 128, 158
 - advanced, 163
 - equations of motion, 128, 148
 - greater, 162
 - left, 164
 - lesser, 161
 - Matsubara, 159
 - retarded, 163
 - right, 164
 - time-ordered, 164
- photon, 479
 - equations of motion, 479
 - noninteracting, 480, 502, 526
- two-particle, 126
 - exact expansion, 132
 - Hartree, 358
 - Hartree-Fock, 358
 - irreducible kernel, 365, 373
 - reducible kernel, 365
 - second Born, 359, 364
 - T-matrix pp, 387
- Gross-Pitaevskii equation, 218
 - soliton, 222
- GW approximation, 212, 326, 399, 436, 495, 512, 528, 560, 639
- gyromagnetic ratio, 5, 59, 79
- H-theorem, 553
- hafnian, 482
- Hamiltonian, 32
 - Born-Oppenheimer, 470
 - electron-phonon, 469
 - electron-photon, 459
 - interaction, 32
 - noninteracting, 29
 - on the contour, 111, 130
 - single particle, 5

- Hartree
 - equations, 217
 - potential, 216
 - time-dependent equations, 220
 - two-particle Green's function, 358
- Hartree plus screened exchange, 376
- Hartree–Fock
 - approximation, 223
 - equations, 224
 - potential, 223, 265
 - time-dependent equations, 226
 - two-particle Green's function, 358
- Heaviside function, 36, 140
 - Fourier transform, 164
 - on the contour, 113, 137
- Hedin equations
 - diagrammatic derivation, 398
 - from generating functional, 661
- Hedin–Baym equations, 495
- Heisenberg model, 64
- Heisenberg picture, 85, 110, 333
 - on the contour, 110, 123
- Hellmann–Feynman theorem, 267, 470
- Helmholtz energy, 596
- Helmholtz theorem, 453
- Hilbert space, 1
 - N distinguishable particles, 9
 - N identical particles, 15
- Hilbert transformation, 674
 - embedding self-energy, 56, 254
 - general property, 264
 - Green's function, 175
 - self-energy, 260
- Holstein model, 69
- hopping integrals, 58
- Hubbard model, 58
 - dimer, 42
- identical particles, 10
- incoherent regime, 552
- insulator, 48
- ionization energy, 172, 180
- irreducible kernel for G_2 , 365, 373
- Kadanoff–Baym equations, 208, 241
- electron–phonon, 514
- open systems, 246
- particle–phonon systems, 499
- Keldysh component
 - advanced, 140
 - anti-time-ordered, 142
 - greater, 137
 - left, 138
 - lesser, 137
 - Matsubara, 138
 - retarded, 140
 - right, 138
 - time-ordered, 141
- Keldysh formalism, 134
- Keldysh space, 137
- ket, 1
 - empty, 18
 - momentum–spin, 6
 - null, 10, 18
 - position–spin, 5
 - distinguishable particles, 8
 - identical particles, 13, 14
- Klein functional, 292
- KMS relations, 248
 - Green's function, 159
 - n -particle Green's function, 126
 - polarization, 268
 - self-energy, 236
- Kondo effect, 301
- Kondo plateau, 302
- Konstantinov–Perel' formalism, 133
- Koopmans' theorem, 227
- Kramers–Kronig relations, 674
- Kubo formula, 334
- Kubo–Martin–Schwinger relations
 - see KMS relations, 126
- Lagrangian for particles and em fields, 453
- Landau damping, 432
- Landauer–Büttiker formula, 254
 - time-dependent generalization, 648
- Lang–Firsov transformation, 74
- Langreth rules, 136, 243
- Laplace formula, 581
 - generalized, 585

Index

695

- Larmor diamagnetism, 90
- left function, 138
- Lehmann representation
 - Green's function, 167, 168, 172
 - response function, 340
- lesser function, 137
- Levi-Civita tensor, 34, 92, 454
- lifetime, 173, 175, 216, 222, 264
 - G_0W_0 , 441
 - phonons, 519
 - second Born, 412
- Lindblad equation, 570
- Lindblad operators, 570
- Lindhard function, 423
- linear response theory, 333
- linked cluster theorem, 277
- Liouville-von Neumann equation, 566
- Lippmann-Schwinger equation, 387, 656
- loop rule
 - for G , 200
 - for G_2 , 362
- Lorentz force, 92, 323, 451
- Luttinger liquid, 299, 415
- Luttinger-Ward functional, 291
- Luttinger-Ward theorem, 296
- magnetic moment operator, 89
- Markovian approximation, 544, 569
- Martin-Schwinger hierarchy, 125, 460
 - particle-phonon systems, 480
- Matsubara
 - formalism, 134
 - frequencies, 153, 260
 - function, 138
 - Green's function, 152
- Maxwell equations, 451
- Maxwell-Lorentz equations, 452
- MBPT, 133
- Meir-Wingreen formula, 252
 - proportionate couplings, 253
- Meissner effect, 90
- memory
 - from embedding, 150, 152
 - from interaction, 152
- metal, 48
- model
 - Anderson, 54, 154, 176, 255, 299
 - BCS, 64
 - constant interaction, 303
 - Fröhlich, 69
 - Heisenberg, 64
 - Holstein, 69
 - Hubbard, 58
 - pairing, 65
 - Pariser-Parr-Pople, 37
 - Su-Schrieffer-Heeger, 69
 - two bands, 186
- model Hamiltonian, 39
- Mott transition, 386
- nanotubes, 50
 - armchair, 50
- natural orbitals, 604
- NEGF, 123
- normal mode, 467
- occupation operator, 29, 33, 40
- one-particle density matrix, 404
- operator
 - anti-chronological ordering, 83
 - anti-time ordering, 83
 - chronological ordering, 81, 161
 - contour ordering, 94
 - correlator, 113, 136
 - first quantization, 27
 - contour evolution, 158
 - Green's function, 147
 - Hamiltonian, 9
 - Hartree potential, 217
 - Hartree-Fock potential, 223
 - potential energy, 9
 - self-energy, 235
 - spectral function, 55, 173
 - width operator, 258
 - second quantization, 27
 - annihilation, 19
 - contour evolution, 108
 - creation, 18
 - current density, 90, 335
 - density, 21, 27, 31, 125

- density matrix, 99
- diamagnetic current density, 88, 316, 460
- electric field, 457
- electron pair, 65
- electron–phonon Hamiltonian, 469
- electron–photon Hamiltonian, 459
- evolution, 82
- field, 18
- Hamiltonian, 32
- interaction Hamiltonian, 32
- magnetic moment, 89
- momentum–stress tensor, 91
- n*-body, 32, 124
- noninteracting Hamiltonian, 29
- occupation, 29, 33, 40, 58, 71, 154
- one-body, 31, 124, 153, 347
- paramagnetic current density, 88, 125, 316, 460
- potential energy, 27
- spin, 34, 59
- total momentum, 90
- total number of particles, 28
- total spin, 44, 61
- two-body, 32
- vector potential, 457
- time ordering, 81
- optical gap, 188
- overlap matrix, 37
- pair correlation function, 336, 608
- pairing model, 65
- paramagnetic current density, 88, 125, 460
 - in terms of G , 125, 316
- Pariser–Parr–Pople model, 37
- particle–hole symmetry, 60
- partition function, 100
- Pauli exclusion principle, 10, 33, 524
- Pauli matrices, 34
- Pauli paramagnetism, 59, 60, 89
- Peierls instability, 73
- phonon, 70, 468
 - bare, 468
 - coherences, 546
 - dressed, 512
- occupation, 546
- phonon branch, 468
- photon, 473
- photoelectron, 179
- photoemission spectroscopy, 179
 - angle-resolved, 181
 - bosons, 181
 - inverse, 181
 - time-resolved and angle-resolved, 181
- photon, 457
- plasma frequency, 251, 429
- plasmons, 414, 429
- Poisson equation, 458
- polarization, 209
 - dressed expansion in G and W , 210
 - fluctuation–dissipation theorem, 269
 - KMS relations, 268
 - reducible, 210, 303, 368
 - spin-independent, 415
- polarization cloud, 69
- polaron, 69
- predictor corrector, 635
- probability amplitude, 4
- pure state, 99
- quantum average, 85, 93
- quantum beats, 649
- quantum number, 157
- quantum of conductance, 255, 302
- quasi-momentum, 48, 181, 186
- quasi-particle, 69, 157, 186, 261, 264
 - effective mass, 441
 - energy, 263, 414
 - G_0W_0 , 442
 - lifetime, 264
 - G_0W_0 , 441
 - second Born, 412
- renormalization factor, 264
 - G_0W_0 , 449
 - phonons, 519
 - second Born, 414
 - Ward identity, 402
- wavefunction, 169, 172
- width, 258, 263
 - embedding, 252

<i>Index</i>	697
<hr/>	
<i>G₀W₀</i> , 441, 446 second Born, 412 Random Phase Approximation, 426 Redfield equation, 569 reducible kernel for <i>G</i> ₂ , 365 removal energy, 172 renormalization factor, 264 second Born, 414 resonance phenomenon, 629 response function, 557 current, 336 current-density, 336 density, 210, 303, 336, 368 noninteracting, 345, 422 RPA, 425 RPA, 561 retardation effects, 210, 235 retarded function, 140 Riemann–Lebesgue theorem, 261, 435 right function, 138 Schrödinger equation, 80 nonlinear, 218 single-particle, 161 screened interaction, 209 fluctuation-dissipation theorem, 269 particle–phonon systems, 492 RPA approximation, 428, 437, 495 Thomas–Fermi, 427 screened Luttinger–Ward functional, 310 screening density, 435 second quantization, 17 second Born self-energy, 208, 360, 557, 638 two-particle Green’s function, 359, 364 self-consistency, 216 cancellation with vertex correction, 421 self-energy, 152, 204, 487 Φ-derivable, 287, 314 particle–phonon systems, 499 correlation, 238, 243, 262, 498 dressed expansion in <i>G</i> , 207, 488 dressed expansion in <i>G</i> and <i>D</i> , 491 dressed expansion in <i>G</i> and <i>W</i> , 210 dressed expansion in <i>G</i> , <i>D</i> , and <i>W</i> , 492 Ehrenfest, 491, 498 embedding, 56, 150, 151, 249 WBLA, 57, 642 exchange-correlation, 210, 493 Fan–Migdal, 496, 512, 529 <i>G₀W₀</i> , 327, 438, 446 <i>GW</i> , 212, 326, 399, 436, 495, 512, 528, 560, 639 <i>GW</i> + exchange, 560 Hartree–Fock, 206, 223 ionization, 184 KMS relations, 236 phonon, 488 dressed expansion in <i>G</i> , 490 dressed expansion in <i>G</i> and <i>D</i> , 490 dressed expansion in <i>G</i> , <i>D</i> , and <i>W</i> , 492 reducible, 282 second Born, 208, 286, 411, 638 T-matrix ph, 328 T-matrix pp, 328 T-matrix pp + exchange, 328, 387 self-interaction error, 218 semiconductor, 48 semiconductor Bloch equations, 533 semiconductor electron–phonon equations, 549 semi-metal, 52 skeleton diagrams, 206, 487 Slater determinant, 25 soliton, 222 source field method, 400, 497, 661 spectral function, 55, 173, 262 Anderson model, 55, 176 BCS model, 389 broadening, 57, 175, 263 electron gas <i>G₀W₀</i> approximation, 446 Hartree approximation, 222 phonons, 517 spin operator, 34, 44, 59, 61 spin-polarized electron gas, 231 Stirling formula, 598 Su–Schrieffer–Heeger model, 69	

698

Index

- T-matrix approximation (ph), 328
T-matrix approximation (pp), 328, 387
 two-particle Green's function, 387
Tamm-Danoff approximation, 382
tensor product, 9
theorem
 Bloch, 48, 465
 Cauchy residue, 154, 673
 fluctuation-dissipation, 646
 Green's function, 165, 170
 phasonic Green's function, 506, 517
 polarization, 269
 response function, 339
 screened interaction, 269
 self-energy, 258
 T-matrix, 330
Gell-Mann-Low, 105
Hellmann-Feynman, 267, 470
Helmholtz, 453
linked cluster, 277
Luttinger-Ward, 296
Riemann-Lebesgue, 261, 435
virial, 651
Wick, 129, 481
Thomas-Fermi
 screening length, 418, 429
Thomas-Reiche-Kuhn sum rule, 342
time ordering operator, 81
time-ordered function, 141
time-resolved photoabsorption, 348
time-stepping technique, 633, 637
Tomonaga-Luttinger liquid, 299
transfer matrix, 388
two-particle XC function, 337, 367, 374
vacuum diagrams, 197
valence band, 48, 52
valence electrons, 37
van der Waals equation, 222
vertex function, 394, 401, 664
vibrons, 70
virial theorem, 315, 651
Ward identities, 355, 401
wavefunction
 N identical particles, 16
 one particle, 4
 two distinguishable particles, 8
 two identical particles, 12, 14
WBLA, 57, 255, 299, 564, 642
Wick's theorem, 129, 131, 132
 phasonic Green's functions, 481
Wide-Band Limit Approximation
 see WBLA, 57
width operator, 258
 second Born, 412
Wigner-Seitz radius, 230, 388, 420
Yukawa interaction, 418, 429, 436
Zeeman splitting, 649
zero-temperature assumption, 107
zero-temperature formalism, 135