Subject Index

a

adiabatic compression 326
adiabatic gas law 95
adiabatic invariant 34
advanced tokamak 600
Alfven speed 148
ambipolarity 224
Ampere's law 18, 52
anisotropic pressure equilibria 130
ARIES advanced tokamak reactor 604
atomic and molecular processes 359
– charge exchange 329, 360
– dissociation 360
– dissociative ionization 360
– dissociative recombination 360
– elastic scattering 360
– excitation 360
– ionization 329, 360
– molecular ionization 360
– radiation emission 363
– rate-limiting reaction coefficients for D_2 362
axisymmetric toroidal equilibria 107

b

banana (collisionless) regime 63
beta limit 581
– normalized β_N 583
– Troyon limit 583
Bickley functions 512
binding energy 1
blanket and shield 593
blob transport 422
Bohm diffusion 377
Boltzmann neutral particle transport equation 485
Boltzmann plasma transport equation 68, 87
bootstrap current 251, 592
Bremsstrahlung 556
burning plasma dynamics 561

c

canonical angular momentum 36, 56, 70, 433
carbon equilibrium charge state distribution 367
Chang-Hinton neoclassical thermal diffusivity 256
Chew-Goldberger-Low theory 170
Christoffel symbols 263, 620
compound nucleus 1
conductive heat flux 90, 137
constants of motion 33
collisional energy transfer 15, 80, 332
collisional regime 63
collisionless regime 63
collisional friction models 223, 227, 238, 248, 386
collisional transport mechanisms 215
– across field lines 216, 217, 218
– along field lines 215, 217, 218
– friction force 220
– gyromotion 217, 219
– thermal force 220
collisions
– Coulomb logarithm 12
– energy transfer time 15
– frequency 63, 224
– impact parameter 11
– Krook collision operators 84
– potential 8
– Rutherford scattering 10
– scattering cross section 1
– scattering operator in Fokker-Planck theory 74
– 90° scattering cross section 13
– 90° deflection time 14
Coulomb force 2, 7, 11, 557
critical fast ion energy 334
current drive
– effect on reactor design 591

– electron cyclotron resonance 351
– fast wave ion cyclotron resonance 350
– figure of merit 351
– inductive 323
– lower hybrid resonance 349
– neutral beam injection 336
curvilinear coordinates 619
cyclotron radiation 557

d

Debye length 7
DEMO 601
density limits
– disruption radiative collapse 567
– divertor thermal collapse 580
– effect on reactor design 588
– electromagnetic 577
– empirical Greenwald 581
– MARFE 479, 576
– thermal radiative instability 578
diamagnetism 38, 111
dielectric tensor 339
differential operators in generalized geometery 285, 619
diffusion coefficients 62, 427
– Bohm 377
– classical 64
– gyro-Bohm 298
– in partially ionized gas 260
– neoclassical 62
– Pfirsch-Schluter 63
– from momentum balance 427, 430
– magnetic fluctuation 301
– turbulent, Kadomtsev mixing length estimate 299
– turbulent, quasilinear estimate 298
– turbulent, weak turbulence estimate 299
diffusion equation 429, 430
diffusive heat flux poloidal distribution 137
dimensions and units 613
Discrete Ordinates method 533
disruptions 565
– causes 567
– current limit 567
– density limit 567
– tearing mode limits 196
divertor 373
– Bohm diffusion 377
– configuration 374
– detached regime 383, 400
– drifts 393
– electrostatic potential 406
– high-recycling regime 383
– impurity retention 385, 413
– model problems 416
– one dimensional model 376
– parallel current 407
– parallel transport 378, 386, 404, 413
– processes taking place 376
– radial transport 376, 403
– sheath-limited regime 382
– thermal instability 388
– 2D fluid model 391
– thermoelectric currents 396
– "two-point" model 380
double-adiabatic model 100
Dreicer velocity 15
drift kinetic theory 68, 173, 241
drifts
– curvature 30, 46, 53, 186, 393, 408, 436
– diamagnetic 194, 394
– $E \times B$ 26, 54, 394, 411, 435
– grad B 27, 46, 53, 186, 393, 408, 436
– in drift kinetic theory 71
– polarization 29

e

Ejima coefficient 323, 591
electric field 18, 248
ELMs (edge localized modes) 467
– instability analysis 472
– MHD ballooning-peeling 470
– MHD peeling modes 468
electromagnetic stress tensor 20
electromagnetic waves
– physics 342
– propagation 339
– ray tracing 341
electrostatic potential 18, 406, 410, 433
elongated equilibria 132, 283
energy confinement time
– definition 549
– effect on reactor design 587

– empirical correlations 551
– experimental determination 550
energy principle 175, 181, 189, 190, 468, 470
equivalent toroidal models 134
equipartition of energy 89
evanescent region 347
$E \times B$ shear stabilization 444
exponential integral function 493

f
Faraday's law 17
fluctuation levels 298
fluid theory 87, 426
– anisotropic pressure tensor model 98
– charge density 91
– continuity equation 88, 286, 378, 388, 391, 426
– current density 91
– energy balance equation 88, 90, 94, 378, 388, 391, 428
– energy flow 90
– energy flux balance equation 88, 90
– heat conduction 90
– heat flux 90
– inertial force 287
– mass density 91
– mass source 91
– mass velocity 91
– MHD model 95, 169
– moments of the Boltzmann equation 87
– momentum balance equation 88, 90, 105, 287, 378, 387, 391, 427
– Ohm's law 93
– 'one-fluid' model 91
– pinch velocity 427, 430
– pressure tensor 89
– viscosity coefficients 289
– viscous forces 288
fluxes,lowest order perpendicular heat and particle 102
flux surfaces
– definition 55, 107
– analytical approximations 113, 115
– elongated 132
– equivalent toroidal models 134
– Grad-Shafranov equation 110
– Shafranov shift 122, 133
flux surface average 109, 132
Fokker-Planck
– collision operator 71
– Lorentz model 75
– theory of collisions 71, 242
force-free currents 105
fueling
– neutral beam injection 329
– neutral gas injection 542
– neutral recycling 542
– pellet injection 542
fusion
– breakeven criterion 4
– progress 5
– reaction rate 2
– reaction types 4
Fusion-fission hybrid 603
Fusion Nuclear Science Facility (FNSF) 602

g
Gauss' law 17
Grad-Shafranov equation 110
gyrofluid theory 318
gyrokinetic theory 316
gyromotion 23
– guiding center 24
– gyrofrequency 24
– gyroradius 23

h
Hall effect 261
heating
– adiabatic compression 326
– electron cyclotron resonance 348
– inductive (ohmic) 325
– ion cyclotron resonance 346
– lower hybrid resonance 347
– neutral beam injection 329
H-mode
– confinement scaling 553
– effect of recycling neutrals on edge profiles 443
– plasma edge profiles 439
– pinch velocities & diffusion coefficients 441
– power threshold 425

i
impurities
– concentration at center of plasma 225
– maximum tolerable fractions 560
– production 365
– radiation 367, 559
– radiative mantle & divertor 480
– maximum radiative power loss 369
– temperature for full ionization 369
index of refraction 148
inductive volt-seconds 590
instabilities-free energy sources and constraints 165
instabilities-hydromagnetic 168
– ballooning 189
– ballooning-peeling 470
– Chew—Goldberger—Low theory 170
– curvature, good and bad 188, 191
– energy principle 175
– firehose 172
– flute (interchange) 46, 183
– guiding center theory 172
– horizontal displacements 117
– internal kink 188
– kink 181, 468
– Mercier criterion 189
– MHD theory 169
– normalized pressure gradient 192
– peeling 468
– pinch 180
– resistive tearing 196
– shear parameter 192
– shear stabilization 188
– stability diagram for kink instabilities 183
– Suydam criterion 189
– toroidal Alfven 337
instabilities-kinetic 202
– collisionless drift 203
– drift wave 193
– electron temperature gradient 205
– electrostatic 202, 293
– ion temperature gradient 206, 286
– loss cone & drift cone 48, 207
– vertical displacement 117
instabilities-magnetic
– sawtooth 211
– magnetic islands 200, 299
instabilities-thermal radiative
– burning plasma 561
– disruption radiative collapse 569
– divertor 388
– MARFEs 476
– radial in plasma edge 449
International tokamak program 597
Ion orbit loss 433
Isobaric surfaces 105, 107
ITER 599

k
Krook collision operators 84

l
Landau damping 149
last closed flux surface (LCFS) 373
Legendre polynomials 486, 492
L-H transition
– $E \times B$ shear stabilization of turbulence 444
– power flux threshold 459
– possible 'trigger' mechanisms 448
– power threshold 425, 588
– temperature gradient threshold 459
– velocity spin-up 461
limiter 374
L-mode confinement
– confinement scaling 552
– pinch velocities & diffusion coefficients 441
– plasma edge profiles 439
lithium reserves 5
Liouville equation 67
loss cone 45

m
magnetic
– diffusion time constant 128
– field diffusion 128
– fluctuations 299
– flux conservation 129
– flux surfaces 37, 55, 107
– islands 200, 299
– moment 25, 33
– pressure 21
– Reynold's number 97

– viscosity 97
magnetic diffusion time constant 128
magnetic field diffusion 97, 127
magnetization 40
MARFEs 476
– density limit 479
– growth rate 478
Maxwell-Boltzmann distribution 7, 173
MHD theory 95, 169
MHD kink mode limits on safety factor 183, 584, 590
Miller equilibrium flux surface 132
mirror confinement 43
– confinement time 46
– curvature and gradB drifts 46
– flute instabilities 47
– loss cones 45
– loss cone instabilities 48
– loss fraction 45
– minimum-B mirror 46
– tandem mirror 48
– mirror ratio 45
– simple mirror 43
mobility coefficient 260
momentum confinement times
– experimental 282
– theoretical gyroviscous 281
momentum transfer frequencies 428
Monte Carlo methods 536

n

neoclassical transport—see transport, neoclassical
neoclassical viscosity
– gyroviscous torque 267, 431
– parallel viscous force 269, 431
– perpendicular viscous torque 267, 431
– toroidal geometry rate-of-strain tensor 263
– toroidal viscous force 265
– viscosity coefficients 270
– viscous stress tensor 264
neutral particle transport
– average neutral energy 531
– Boltzmann neutral particle transport equation 485
– boundary conditions 502
– charge-exchange model 487
– collision probability methods 514
– current 502
– diffusion theories 496
– Discrete Ordinates method 533
– elastic scattering model 488
– escape probabilities 509, 517, 522, 528
– first collision source 491
– integral transport theory 504
– interface current balanace theory 364, 517
– Marshak vacuum boundary condition 495, 498
– Monte Carlo methods 536
– multidimensional 500
– Navier–Stokes 541
– partial currents 504
– P_N equations 493
– recombination model 491
– scalar flux 502
– streaming operators 503
– Transmission-Escape Probability (TEP) method 519, 525
– transmission probabilities 509, 517, 519, 528

o

Ohm's law 16, 93, 94, 95, 193, 392
ordering
– large collision frequency 235, 243
– small inverse aspect ratio 244
– small gyroradius 235, 243
– strong field transport 100
orbits
– banana 60
– distortion 253
– potato 254
– squeezing 255
– turning point 58
– time required to complete 59, 63
– trapped particles 57
– Ware pinch 253

p

Paleoclassical electron thermal diffusivity 258
paramagnetism 111
permeability 18
permittivity 18
Pfirsch-Schluter diffusion coefficient 63

physical constants 612
pinch-diffusion particle flux 428
pinch velocity 427, 430
plasma
– beta 106, 111, 112, 118, 125
– criterion 8
– electrostatic waves 158
– equilibria 105
– frequency 9
– inductance 591
– internal inductance 115, 323
– resistivity 16, 78, 80, 92, 325
– safety factor 55, 119
plasma-facing components 593
– fatigue limits 595
– heat fluxes 594
– radiation damage 596
– stress limits 594
– temperature limits 595
plasma formulas 627
plasma-material interactions
– chemical sputtering 366
– physical sputtering 365
– recycling 358
pressure gradient, normalized , α 192
pressure tensor 89
private flux region 375
Poisson's equation 7, 18
Poloidal rotation 272
– Hirshman-Sigmar theory 273
– density poloidal asymmetries 278
– Shaing-Sigmar-Stacey viscosity 275
– Stacey-Sigmar theory 276
– velocity spin-up 461
POPCON plots 563
Poynting vector 20, 555

r

radial electric field 248, 281
radiation
– bremsstrahlung 556
– cyclotron 557
– impurity 367, 559
– radiation fields 554
radiative cooling 369, 480
radiative divertor 481
radiative instabilities—see instabilities thermal
radiative mantle 480
recycling of neutral particles 358
– energy reflection coefficient 358
– neutral penetration 364
– particle reflection coefficient 358
– re-emission 358
– tokamak plasma fueling 542
resistivity 16, 78, 92
– neoclassical 325
– Lorentz gas 80
resonances
– ion cyclotron 149
– ion-ion 343
– lower hybrid 147, 162, 343
– upper hybrid 147, 343
Rosenbluth potentials 74
rotational transform 55
Runaway electrons 16
Rutherford scattering cross-section 12

s

scrape-off layer (SOL) 373
second stability regime 472
separatrix 373, 375
Shafranov shift 122
sheath 355
– sheath power transmission coefficient 357
– secondary electrons 357
– sheath potential 355
shear
– magnetic field 55
– reduction of turbulent transport 306, 310, 313, 314, 444
– ballooning mode shear parameter S 192
Sonine (Laguere) polynomials 236
sputter yields 366
Subcritical Advanced Burner Reactor (SABR) 604

t

thermal diffusivity
– chaotic magnetic island overlap 315
– drift Alfven modes 311
– drift resistive ballooning modes 314
– electron temperature gradient modes 312

– experimental interpretation 429
– ion temperature gradient modes 307
– paleoclassical 258
– neoclassical Chang-Hinton 256
– shear stabilization 310, 313, 314
– thermal instability modes 311
– trapped electron modes 313
thermoelectric current 396
thermonuclear temperatures 3
tokamak confinement 51
– banana orbits 60
– canonical angular momentum 56
– curvature and gradB drifts 53
– $E \times B$ drifts 54
– flux surfaces 55, 107
– rotational transform 55
– trapped particles 57
toroidal field magnets 592
Transmission-Escape Probability (TEP) method 519, 525
transport, classical 222
– closure of fluid equations 234
– transport parameters 238
transport in partially ionized gas 259
transport, neoclassical
– drift kinetic derivation 241
– extended 247
– in Miller flux surface geometry 286
– multifluid 231
– toroidal Pfirsch-Schluter 225
– trapped particles 241
transport, turbulent
– blobs 422
– electron temperature gradient modes 312
– electrostatic drift waves 293
– direct interaction 302
– drift Alfven modes 311
– drift resistive ballooning mode 314
– drift wave eigenmodes 304
– gyrofluid theory 318
– gyrokinetic theory 316
– ion temperature gradient modes 296, 307
– magnetic fluctuations 299
– mode coupling 301
– direct interaction approximation 302, 304
– quasilinear transport 296
– saturated fluctuation levels 298
– shear stabilization 310, 313, 314, 444
– thermal instabilities 31
– trapped electron modes 313
– zonal flows 321
trapped particles 57

v
velocity (poloidal) spin-up 461
– bifurcation 466
– fluid calculatioin 463
– neoclassical spin-up 463
– poloidal asymmetries 464
vector calculus 617
vector potential 17
viscous torque 264, 288, 431
Vlasov equation 68, 149, 152

w
Ware pinch 61, 253
waves in plasmas
– collisionless dissipation 345
– dielectric tensor 339
– penetration & cutoff 142, 146
– electromagnetic 142, 144
– ion acoustic 165
– ion sound 143
– Langmuir 149
– polarization 145, 343
– refractive index 339
– shear Alfven 147
– ray tracing 341
– upper hybrid resonance 147
– Vlasov theory 152
– wave-wave interactions 301

x
X-point 373
X-region 437
X-transport 435

y
yin-yang coils 47

z
zonal flows 321