

Contents

	<i>Preface</i>	xiii
	<i>Acknowledgments</i>	xv
1	Introduction	1
1.1	Collision frequencies	3
1.2	Random-walk estimates for classical transport in a straight magnetic field	6
1.3	Random-walk estimate for ion heat diffusion in a tokamak	10
1.4	Random-walk estimate of Bohm diffusion	11
	<i>Further reading</i>	12
	<i>Exercises</i>	12
2	Kinetic and fluid descriptions of a plasma	14
2.1	The kinetic equation	14
2.2	Fluid equations	16
	<i>Further reading</i>	20
	<i>Exercise</i>	20
3	The collision operator	22
3.1	Derivation of the Fokker–Planck operator	22
3.2	Electron–ion and ion–impurity collisions	30
3.3	Collisions with a Maxwellian background	35
3.4	Collision operator for fast ions	40
3.5	Ion–electron collisions	42
3.6	Collision operator for relativistic particles	43
3.7	The linearized collision operator	47
3.8	Model operator for self-collisions	53
	<i>Further reading</i>	55
	<i>Exercises</i>	56

4	Plasma fluid equations	59
4.1	Outline of closure in the case of short mean-free path	59
4.2	Lorentz plasma	61
4.3	Onsager symmetry and a variational principle	67
4.4	Spitzer conductivity	71
4.5	Expansion in orthogonal polynomials	74
4.6	Braginskii's equations	76
4.7	Diamagnetic flows	83
	<i>Further reading</i>	88
	<i>Exercises</i>	88
5	Transport in a cylindrical plasma	90
5.1	Particle transport	90
5.2	The influence of viscosity on ambipolarity	94
5.3	Transport of momentum and heat	96
6	Particle motion	99
6.1	Equations of motion	99
6.2	Nearly periodic motion	100
6.3	Guiding-centre motion	103
6.4	Other adiabatic invariants	109
6.5	The drift kinetic equation	113
	<i>Further reading</i>	115
	<i>Exercises</i>	115
7	Toroidal plasmas	117
7.1	Magnetic field	117
7.2	Magnetohydrodynamic equilibrium	121
7.3	Guiding-centre orbits in tokamaks	127
7.4	Non-axisymmetric systems	136
	<i>Further reading</i>	142
	<i>Exercises</i>	142
8	Transport in toroidal plasmas	146
8.1	Transport ordering	146
8.2	Collisionality	148
8.3	Distribution function	150
8.4	Current	153
8.5	Parallel particle and heat fluxes	155
8.6	Flow across flux surfaces	158
8.7	Confinement time	161
	<i>Further reading</i>	164
	<i>Exercises</i>	164

9	Transport in the Pfirsch–Schlüter regime	167
9.1	Ion heat flux	168
9.2	Several species	171
	<i>Further reading</i>	178
	<i>Exercise</i>	178
10	Transport in the plateau regime	179
10.1	Physical picture	179
10.2	Transport laws	182
	<i>Further reading</i>	185
	<i>Exercise</i>	185
11	Transport in the banana regime	187
11.1	Drift kinetic equation	187
11.2	Ion transport	191
11.3	Electron transport	198
11.4	Bootstrap current	205
11.5	Variational principle	211
	<i>Further reading</i>	216
	<i>Exercises</i>	216
12	The moment approach to neoclassical theory	219
12.1	The parallel viscous force	219
12.2	Plasma flows	222
12.3	Collisional regime	227
12.4	Plateau regime	231
12.5	Banana regime	233
12.6	Interpolation between different regimes	236
12.7	Ion rotation and bootstrap current at finite aspect ratio	238
	<i>Further reading</i>	243
	<i>Exercises</i>	244
13	Advanced topics	246
13.1	Poloidal rotation	246
13.2	Toroidal rotation	249
13.3	Nonlinear transport in steep plasma profiles	254
13.4	Orbit squeezing	260
13.5	Neoclassical transport in stellarators	267
	<i>Further reading</i>	270
	<i>Exercise</i>	270
14	Experimental evidence for neoclassical transport	272
	<i>Appendix Useful formulas</i>	276
	<i>Bibliography</i>	281
	<i>Index</i>	287