

# Contents

<b>1</b>	<b>Introduction</b> .....	1
<b>2</b>	<b>Previous Work, Status and Overview</b> .....	5
2.1	Energy Loss in an Unmagnetized One-Component-Plasma (OCP) .	5
2.2	Challenges Imposed by the Magnetic Field .....	11
2.3	Classical-Trajectory-Monte-Carlo (CTMC) Simulations .....	14
2.4	Dielectric Treatment (DT), Vlasov-Poisson Equation, Linear Response (LR) .....	16
2.5	Particle-In-Cell (PIC) Simulations .....	22
<b>3</b>	<b>Binary Collision Model</b> .....	25
3.1	Introductory Remarks .....	25
3.2	Equations of Motion .....	26
3.3	Energy Loss and Velocity Transfer .....	28
3.4	General Interactions, no Magnetic Field .....	29
3.5	Binary Collisions (BC) in a Magnetic Field .....	33
3.6	Parallel Ion Motion .....	39
3.7	Chaotic Scattering and Validity of the Perturbation Treatment .....	42
3.8	Binary Collision Model for Arbitrary Ion Motion in a Strong Field .	51
3.9	Binary Collisions in a Weak Field .....	57
3.10	Impact Parameter Integration and Velocity Averaging .....	61
3.11	Velocity Diffusion (Straggling) of Charged Particles in a Magnetic Field .....	68
<b>4</b>	<b>Dielectric Theory</b> .....	73
4.1	Stopping Power (SP) in Plasmas Without Magnetic field .....	73
4.2	Stopping in Plasmas With Weak Magnetic field .....	76
4.2.1	Small Projectile Velocities .....	77
4.2.2	High Projectile Velocities .....	78
4.3	Stopping in Plasmas With Strong Magnetic Field .....	79
4.3.1	Small Projectile Velocities .....	81
4.3.2	High Projectile Velocities .....	81
4.4	Stopping in the Low-Velocity Limit at Arbitrary Field Strengths ...	83
4.5	High-Velocity SP in a Magnetized Plasma .....	85
4.5.1	Heavy Ions With Rectilinear Trajectories .....	87

4.5.2	Weakly Coupled Plasma with Strong Magnetic Fields . . . . .	91
4.5.3	Light Ions, The Effect of the Cyclotron Rotation . . . . .	93
4.6	Reduced LR (RLR) Treatment . . . . .	96
4.6.1	RLR, LR and BC Treatments Without Magnetic Field . . . . .	98
4.6.2	RLR, LR and BC Treatments With Strong Magnetic Fields . . . . .	100
4.7	Conformity Between Reduced LR and BC approaches . . . . .	106
<b>5</b>	<b>Quantum Theory of SP in Magnetized Plasmas . . . . .</b>	<b>109</b>
5.1	Dielectric Theory . . . . .	109
5.2	Equation of State for Quantum Magnetized Plasmas . . . . .	115
5.2.1	Critical Temperature . . . . .	115
5.2.2	Fully Degenerate Electron Plasma . . . . .	116
5.2.3	Semiclassical and Classical Limits . . . . .	118
5.3	Dielectric Function, Fully Degenerate Plasma . . . . .	118
5.3.1	Fully Degenerate Plasma in a Strong Magnetic Field . . . . .	120
5.3.2	Acoustic Plasma Resonance . . . . .	121
5.4	Dielectric Function, Semiclassical Limit . . . . .	121
5.5	Stopping Power in a Magnetized Quantum Plasma . . . . .	124
5.5.1	Low-Velocity Stopping Power in a Semiclassical Regime . . . . .	124
5.5.2	Stopping power in an Infinitely Strong Magnetic Field, Low-Velocity Limit . . . . .	126
5.5.3	Stopping power in a Strong Magnetic Field in the Nearly Degenerate Regime . . . . .	129
5.6	Binary Collision Treatment, Conformity Between BC and RLR . . . . .	130
5.7	Correspondence Between Quantum and Classical BC Treatments . . . . .	134
5.7.1	Cartesian Basis . . . . .	134
5.7.2	Cylindrical Basis . . . . .	137
5.8	Averaged Classical Second-Order Energy Transfer . . . . .	140
<b>6</b>	<b>Applications and Illustrating Examples . . . . .</b>	<b>143</b>
6.1	Electron Cooling in Storage Rings . . . . .	143
6.1.1	Energy Loss and Drag Force . . . . .	144
6.1.2	Cooling Forces . . . . .	145
6.1.3	Emittance and momentum spread . . . . .	148
6.2	Electron Cooling in Penning Traps . . . . .	150
6.2.1	Modeling of the Cooling Process in a Trap . . . . .	151
6.2.2	Cooling of Protons and Highly Charged Ions . . . . .	153
6.2.3	Cooling of Antiprotons and Protons by Electrons and Positrons . . . . .	159
<b>7</b>	<b>Summary and Conclusion . . . . .</b>	<b>165</b>
<b>A</b>	<b>Dielectric Function of the Magnetized Electron-Ion Plasma . . . . .</b>	<b>169</b>
<b>B</b>	<b>Anomalous Term . . . . .</b>	<b>171</b>

<b>C</b>	<b>Dielectric Function of the Magnetized Quantum Plasma . . . . .</b>	<b>173</b>
<b>D</b>	<b>Some Properties of the Function <math>F_{nn'}(\zeta)</math> . . . . .</b>	<b>175</b>
	<b>References . . . . .</b>	<b>177</b>
	<b>List of Symbols and Abbreviations . . . . .</b>	<b>183</b>