

Basic Plasma Physics

Instructor: Antonius Otto

October 22, 2008

Contents

| | | |
|----------|---|-----------|
| 1 | Basic Elements of the Physics of Charged Particles | 3 |
| 1.1 | Preliminaries | 3 |
| 1.2 | Basic Properties and Definitions | 4 |
| 1.2.1 | Plasma definition: | 4 |
| 1.2.2 | What is a Plasma - Debye Shielding and Plasma Parameter | 6 |
| 1.2.3 | Plasma Frequency | 10 |
| 1.3 | Coulomb Cross section for Momentum Exchange | 11 |
| 1.4 | Collision frequency | 14 |
| 1.5 | Plasma in a Fluid Limit | 15 |
| 1.6 | Basic plasma equations | 15 |
| 1.6.1 | Maxwell's Equations | 15 |
| 1.6.2 | Lorentz Equations of Motion | 16 |
| 1.6.3 | Examples of Kinetic Equations | 17 |
| 2 | Single Particle Dynamics | 21 |
| 2.1 | Gyro Motion | 21 |
| 2.2 | Electric Field Drift | 23 |
| 2.3 | Magnetic Moment and Adiabatic Invariants | 25 |
| 2.4 | The Guiding Center Approximation and Magnetic Drifts | 26 |
| 2.4.1 | Magnetic Gradient Drift | 27 |
| 2.4.2 | Magnetic Curvature Drift | 28 |
| 2.5 | Summary of Particle Drifts and Drift Currents | 29 |
| 2.6 | Magnetic Mirror | 30 |
| 2.7 | More on Adiabatic Invariants | 33 |
| 2.7.1 | General Invariance: | 33 |
| 2.7.2 | Second (Longitudinal) Adiabatic Invariant | 34 |
| 2.7.3 | Third (Drift) Adiabatic Invariant | 35 |
| 2.7.4 | Violation of Adiabatic Invariants | 35 |

| | | |
|----------|---|-----------|
| 3 | Magnetohydrodynamics | 36 |
| 3.1 | Derivation of the Fluid Plasma Equations | 36 |
| 3.1.1 | Definitions | 36 |
| 3.1.2 | Fluid Moments | 37 |
| 3.1.3 | Typical Fluid Approximations | 39 |
| 3.2 | Two Fluid Plasma Equations | 41 |
| 3.3 | Single Fluid or MHD Equations | 42 |
| 3.3.1 | Derivation of the MHD equations: | 42 |
| 3.3.2 | Approximations used in the MHD equations: | 44 |
| 3.4 | Properties of the MHD equations: | 46 |
| 3.4.1 | Frozen-in Condition | 46 |
| 3.4.2 | Entropy and Adiabatic Convection | 48 |
| 3.4.3 | Conservation laws: | 52 |
| 3.5 | MHD Equilibria | 53 |
| 3.6 | MHD Stability | 58 |
| 3.6.1 | Energy principle | 58 |
| 3.6.2 | Applications of the energy principle | 59 |
| 3.7 | Magnetohydrodynamic Waves | 60 |
| A | Appendix | 67 |
| A.1 | Tables of Plasma Parameters | 67 |
| A.2 | Definition of the radius of curvature | 69 |