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Chapter 1

Introduction

1.1 Numerical Simulations

As there are several theoretical branches within the field of plasma physics, magnetohydrodynamics, kinetic theory (Note to self: Need better overview, and citations), that are suited to investigate plasma physics at different scales and different phenonema, there are also different approaches to conduct numerical plasma studies. Plasma simulation codes can be classified along the extent they are using a kinetic kinetic or fluid description of the plasma. Kinetic codes include Vlasov simulations (cite), Fokker-Planck simulations (Cite) and particle codes like the Particle-in-Cell code, that the development of, was a large part of this master thesis. Plasma fluid simulations are called MHD and are based on magnetohydrodynamical theory, (mention some). In the fluid description some of the detailed physics is averaged out and this causes MHD codes to be unsuited to study results depending on some small scale phenomena. Their advantage is that due to the reduced detail they can simulate on a much larger scale. Kinetic simulations generally have more detail and capture more physics (rewrite), and as a tradeof they are restricted to simulate over a physical domain due to limited computation power and memory storage. Since the relevant timescales vary vastly between ions and electrons a multitude of hybrid codes has also been developed. (Search for multitude of hybrid codes and ref). These types of codes can e.g. treat some of the species as fluids and some as particles capturing the wanted phenomena. Particle based codes can also be combined with molecular dynamics code, if the algorithm is unsuited in a regime.

1.2 Particle-in-Cell

To investigate the mechanics involved in a wide variety of plasma phenomenens, computer simulation. Particle-in-Cell, PiC, is simulation model that takes a particle based approach, where each particle is simulated seperately, or a collection.

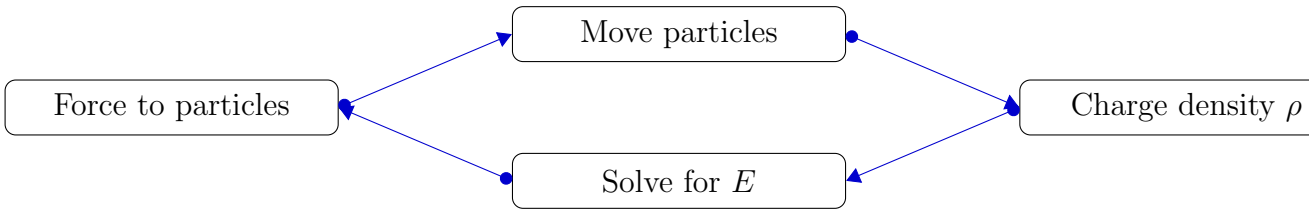

Figure 1.1: Schematic overview of the PIC method

If we naively would attempt to compute the electrical force between each particle, the necessary computational power would grow quickly as the number of particle increases, $\mathcal{O}((\#particles)^2)$. Since a large number of particles is often neccessary the PiC method seeks to the problem by computing the electrical field produces by the particles, and then compute the force on the particle directly from the field instead. From the charge distribution we can find the electric potential through the use of Poissons equation, eq. (1.1), and subsequently find the electrical field from the electrical potential. See fig. 1.1 for an overview of the

$$\nabla^2 \Phi = -\rho \qquad \text{in} \qquad \Omega \tag{1.1}$$