Contents

1 Introduction ........................................... 1
  1.1 Motivation ......................................... 1
  1.2 Discussion of earlier work ......................... 4
    1.2.1 Breaking of nonlinear non-relativistic oscillations with static
          ion background .................................. 4
    1.2.2 Breaking of nonlinear relativistic plasma oscillations with
          static ion background ............................. 6
    1.2.3 Breaking of nonlinear plasma oscillations with ion motion ... 7
    1.2.4 Wave breaking at critical amplitude ................ 9
  1.3 Scope of the thesis ............................... 10

2 Nonlinear evolution of an arbitrary density perturbation in a cold
   homogeneous unmagnetized plasma .................... 12
  2.1 Introduction ....................................... 12
  2.2 Governing equations and the General solution ........ 14
    2.2.1 Sinusoidal perturbation in the density ............. 17
    2.2.2 Sinusoidal perturbation in the particle position .... 17
  2.3 Evolution and breaking of square and triangular wave profiles . . 18
  2.4 First two modes are non-zero ........................ 19
  2.5 Results from the simulation ........................ 19
  2.6 Evolution and breaking of incommensurate modes ........... 22
  2.7 Summary ........................................... 24

3 Nonlinear oscillations in a cold dissipative plasma ............. 26
  3.1 Introduction ....................................... 26
  3.2 Nonlinear plasma oscillations with viscosity and resistivity .... 28
3.2.1 $\alpha = 1$ (viscosity coefficient inversely depends on density) 29
3.2.2 $\alpha = 0$ (viscosity coefficient is constant) 31
3.3 Nonlinear Plasma Oscillations with hyper-viscosity and resistivity 32
3.4 Relation between breaking amplitude and viscous/hyper-viscous coefficient 35
3.5 Summary 37

4 Breaking of longitudinal Akhiezer-Polovin waves 39
4.1 Introduction 39
4.2 Relativistic fluid equations and Lagrange solution 41
4.3 Results from the simulation 44
4.4 Match between theory and simulation 49
4.5 Summary 50

5 Nonlinear oscillations and waves in an arbitrary mass ratio cold plasma 54
5.1 Introduction 54
5.2 Governing equations and perturbation analysis 56
5.3 Standing plasma oscillations 58
5.3.1 sinusoidal velocity perturbations to both electron and ion fluids 58
5.3.2 sinusoidal density perturbations to both electron and ion fluids 59
5.4 Phase mixing of traveling waves 60
5.5 Electron-ion traveling wave solution 64
5.6 Summary 66

6 Breaking of nonlinear oscillations in a cold plasma 67
6.1 Introduction 67
6.2 Results from the simulation 69
6.3 Interpretation of the results 74
6.4 Summary 76

7 Development and breaking of double layers using method of Lagrange variables 78
7.1 Introduction 78
7.2 Governing Equations and the Linear limit 79
7.3 Governing Equation in Lagrange Variables 81
7.4 Exact Nonlinear Solution 83
    7.4.1 Harmonic initial conditions 83
    7.4.2 “Void” like initial conditions 86
7.5 Summary 89

8 Conclusion 90