Preface

Space plasma physics is the study of natural phenomena occurring in the plasma environment of the solar system. Wide ranges of plasma phenomena have been observed to occur in the solar system. These include solar flares, coronal holes, solar wind, variations of interplanetary magnetic field, heliospheric current sheet, collisionless shock waves, magnetospheric boundary layer, patchy and intermittent magnetic reconnection at the earth magnetopause, variations of plasma sheet structures and ring current during magnetospheric substorms, intensification of field-aligned currents and auroral substorms.

The solar wind carries away a part of the solar energy and fills up the interplanetary space with plasmas of solar origin. On the way of expansion, part of the solar wind energy is deposited in the earth's magnetosphere and also in other magnetized planets like Jupiter and Saturn, whereby numerous attractive dramas are played therein. "Aurora" is epilogue of a series of dramas that are played on the stage of the solar terrestrial plasma system. These dynamic displays of the multicolored luminosity have fascinated and puzzled natural scientist down through ages and can be defined as light emitted from excited atmospheric atoms and molecules due to bombardment of hot electrons and protons that precipitate down into the ionosphere from the magnetosphere along magnetic field lines. This seemingly simple phenomena, notwithstanding, the research of auroral physics is not that easy because of complexity and diversity of occurrence conditions of auroral arcs whose activities and forms are very different, depending on local times, latitudes and magnetic activities. There are several observational evidence of quiet and even active discrete
auroral arcs, which result from localized acceleration processes along the magnetic field lines that connect the magnetotail and the ionosphere.

Satellite and rocket observations have revealed a host of auroral plasma processes including large DC perpendicular electric fields ($E_\perp$) associated with electrostatic shocks, relatively weak parallel electric fields ($E_{||}$) associated with double layers, up flowing ions in the form of beams and conics downflowing and upflowing electron beams, several wave modes such as the electrostatic ion cyclotron (EIC), lower hybrid (LH), upper hybrid, VLF, ELF, high frequency waves and associated non-linear phenomena.

The Alfven wave is dominant low frequency transverse mode of magnetized plasma, which propagates along the magnetic field and displays a continuous spectrum even in bounded plasma. Alfven wave named after the Swedish space physicist H. Alfven in one of the most important waves in magnetized plasma. Alfven waves in a plasma were first generated and detected by Allen Baker, Pyle and Wilcox at Berkely, California and by Jephcott in England in 1959 during the “slow pinch” discharge in a hydrogen plasma between two electrodes aligned along a magnetic field. This wave may play an important role in energy transport, in driving field-aligned currents, in particle acceleration and heating and in explaining inverted-V structures in magnetosphere-ionosphere coupling.

The Alfven wave which is excited by the resonant mode conversion has a perpendicular wave length $k_\perp^{-1}$, comparable to the ion gyroradius $\rho_i$, and accompanies an electrostatic component is called as the kinetic Alfven wave. The kinetic Alfven wave (KAW) was first introduced by Hasegawa and Chen (1975) in relation to the plasma heating. Hasegawa and Chen (1976) introduced that kinetic
Alfven wave propagates into the higher density side of the plasma and after the mode conversion dissipates due to both linear and non-linear processes and heats the plasma. Hasegawa and Mima (1978) have discussed the application to diffusion of radiation particles and ring current heating of plasma pause electrons and formation of the stable auroral red arcs as well as viscous interaction between the solar wind and the magnetosphere. The study on kinetic Alfven waves further developed in a two dimensionally inhomogeneous plasma in a curved magnetic field.

The interplay between plasmas and charged dust grains has opened up a new and fascinating research area that of a dusty plasma. The physical processes in dusty plasma are studied extensively because of their many applications to astrophysical and space plasmas as well as in laboratory plasmas. Dusty plasmas exist naturally in astrophysical and space environments such as cometary tails, planetary ring systems, planetary magnetospheres interstellar and circumstellar clouds etc. Nearer the earth, the enhanced radar back scatter from the noctilucent clouds often observed in the polar regions during the summer seasons has been attributed to the presence of dust in the earth’s lower ionospheric regions.

Recently, the presence of charged dust in the mesosphere has been detected by direct rocket probe measurements, and both negatively and positively charged dust grains have been reported. The formation of an artificial dusty plasma in the ionosphere was also revealed during the Space lab2 mission when the space shuttle orbital maneuver system engines were fired. Due to their various applications a number of workers have studied the wave propagation characteristics, damping, drift waves, Alfven wave instabilities, wave scattering, dust crystallization etc. and other collective properties.
There are two important features that distinguish dusty plasmas from the usual multi-component plasmas. First, because of finite size and hence the large mass of the dust particles, the plasma as well as the gyro frequencies of the ions and the dust are widely separated and, consequently, it is possible to separate the modes arising due to the dust and ion inertial effects. Second, the charge on the dust particles can vary owing to either the wave-motion induced electron and ion currents flowing onto the grain surface in the equilibrium charging process. The later are known to be responsible for certain new effects in dusty plasmas, which are absent in multi-component plasmas with different types of ion electron species. For example, it has been shown that the grain charge fluctuations typically give rise to the damping of the waves, which would otherwise propagate as normal modes.

Generally, dust particles in plasma are charged by plasma current, photo-emission, and field emission, etc. The amount of charge acquired by a dust particle is determined by its capacity and the electron and ion thermal current balance to the grain. When an equilibrium charge has been attained by the dust grains, the plasma with charged dust grain may be regarded as simply a multispecies plasma for process with a time scale shorter than the characteristic grain charging time. Many of the interesting investigations pertaining to the dusty plasma fall in this category.

Small-scale intense disturbances of electric field are constantly measured by polar orbiting and Freja satellites in the altitude range from 900 km. to 2\textit{R_E} (\textit{R_E} is the earth radius) above the auroral ionosphere. Direct measurements from satellites and rockets have shown that the discrete flux of keV electrons registered at auroral zone are often correlated with small-scale, localized electromagnetic disturbances some times interpreted as Alfven waves. Because the periods of ULF
Alfven wave are compatible with fundamental field line oscillations and the time scale of particle bounce motion along auroral field lines Alfven waves are considered as powerful agent to explain various observed phenomena in magnetosphere-ionosphere coupling. The ionosphere-magnetosphere coupling mediated by standing Alfven waves have also been treated theoretically. Detection of Alfven wave turbulence has been made by Inter-Cosmos-Bulgaria 1300 satellites as well as more recently with the Freja satellites studying the association of auroral particle precipitation and the Alfven wave.

This thesis is devoted to the currently central problem of auroral plasma physics in the spirits of Dawson's approach to Landau damping of Alfven and kinetic Alfven wave that is the influence of Alfven wave and kinetic Alfven wave on the particle movement field-aligned currents, low frequency emissions in the auroral zone in the magnetosphere. The charged particle trajectories are evaluated in the presence of Alfven and kinetic Alfven waves which can be used to attain an in-depth understanding of the ion-pickup process, which has been extensively studies in the literature by means of both quasilinear theory and numerical simulations. The theory and findings of the investigation are applicable to magnetosphere-ionosphere coupling where field-aligned current and auroral acceleration are explained in terms of Alfven wave and kinetic Alfven wave.

In most of theoretical work, the velocity distribution functions have been assumed to be ideal Maxwellian although most turbulent heating experiments like mirror devices, magnetosphere allow non-Maxwellian, particularly loss-cone distribution functions. Thus in the present work we have also investigated the effects of non-Maxwellian distribution on the Kinetic Alfven wave.
The method of particle aspect analysis has been adopted to study the behavior of Alfven and Kinetic Alfven wave in view of the auroral phenomena. A better understanding of particle orbits is very important for predicting the plasma confinement, high energy particle loss, and heating efficiency in the experimental devices also. To study particle orbits, several techniques of orbit calculations have been already developed. The investigation of charge particle trajectories in the presence of wave paves the way to study the generation of waves, their dispersion relations, currents driven by the waves and the transfer of energy to the particles and hence acceleration of charged particles by the waves in the same sequence of analysis, therefore, may be suitable for the study of auroral electrodynamics.

The present thesis contains six chapters dealing with the various aspects of electromagnetic Alfven waves and Kinetic Alfven waves. The application and importance of the waves have also been indicated for the space plasmas. Before dealing with this problem, we have reviewed the basic phenomena of magnetosphere-ionosphere coupling pertaining to field-aligned currents and auroral acceleration. It is the first chapter of the thesis, in which some aspects are presented to explain discrete aurora, parallel electric field, field-aligned current, perpendicular currents, charged particle acceleration by Alfven wave and kinetic Alfven wave observed by rockets and satellites with their theoretical aspects.

In the second chapter, particle aspect analysis has been applied to evaluate the dispersion relation and associated field-aligned current for Alfven waves in the auroral region. Effect of temperature anisotropy has been examined on the wave and the applicability of the finding is discussed for the magnetosphere-ionosphere coupling. In this and subsequent chapters, the plasma in the acceleration region is
supposed to be composed of two types of charged particles i.e. resonant and non-resonant particles. The non-resonant particles support the oscillatory motion of the wave whereas the resonant particles participate in the energy exchange with the wave.

In the third chapter, Alfvén waves are analysed using particle aspect analysis in magnetospheric plasma. Dispersion relation and associated field-aligned current in the presence of parallel electric field are evaluated. The effect of parallel electric field is included in the zeroth order distribution function through the modification of the particle thermal velocity parallel to ambient magnetic field. Effects of electron beam and temperature anisotropy have been also studies on the wave and applicability is discussed for the auroral acceleration region.

Dispersion relation, growth rate, associated field-aligned current and resonant particle energy of Alfvén wave bi-Maxwellian distribution function in the presence of electron beam and temperature anisotropy have been obtained by evaluating the trajectories of the charged particles in the fourth chapter. It is observed that Alfvén waves can be generated in plasma sheet at substorm times due to electron beam and thermal anisotropy and propagate towards the ionosphere causing current system in the auroral acceleration region. It is also noticed that temperature anisotropy merely affects the growth rate and the acceleration of electron along the magnetic field lines, however the excitation is caused by electron beam velocity. The applicability of investigation is discussed for the magnetosphere-ionosphere coupling.

In the fifth chapter, particle aspect approach is extended for Alfvén waves in dusty magnetosphere. Dispersion relation and associated field-aligned currents are evaluated for Alfvén wave with bi-Maxwellian distribution function in
warm magnetized dusty plasma, consisting of electrons, ions and charged dust particles. Effects of different charge concentrations, dust particles density and the ratio of the temperature of the dust particle to that of electron have been examined on the propagation of Alfven wave. It is found that the dust grain concentration and charge on dust grains reduce the wave frequency of the Alfven, however, the temperature of the dust particles increases the wave frequency. Positively charged dust grain enhances the downward field-aligned current and negatively charged dust grain increases the upward current of the lower auroral ionosphere. Similar effects are also noted for the dust grain number density, whereas, the temperature of the dust grain reduces the field-aligned currents. Applications of the findings are indicated for the space plasma as well as for the laboratory plasma.

In the last chapter, we have investigated the dispersion relation, current and growth rate of the kinetic Alfven wave with loss-cone distribution function in a warm, magnetized dusty plasma, consisting of electrons, ions and charged dust particles. Effects of steepness of loss-cone distribution are discussed on the dispersion relation and the growth rate of the wave. The results are derived for the space plasma parameters appropriate to the auroral acceleration region.

These basic phenomena of excitation of waves, associated currents and the effects of various observational facts taken as the objective of the thesis may provide an opportunity to understand various incidents occurring in our space environment of the earth, especially for magnetosphere-ionosphere coupling. The study of these phenomena may offer an explanation for the various effects on the earth at the substorm times, which have been mysteries for long periods. Further, it
may be also useful to provide the knowledge of the structure of space environments for our polar satellites. A part of the finding of the investigation has been published in national journal and rest is communicated for publication to national and international journals of repute.

The initial start and development of this work was made under the guidance of Prof. M.S. Tiwari, whereas the execution and completion of the work described in the thesis was achieved by the author. The papers have been published under the joint authorship with Prof. M.S. Tiwari and some of the research fellows working in the laboratory. Wherever coauthorships are involved the work was independently done by all the coauthors. The work submitted in this thesis was not submitted earlier by any one of the co-authors and their main contribution is in the form of suggestions of the problem. The detailed formulations and computations given in the thesis were carried out entirely by the author independently. The intermediate results and development of this work have been presented in various symposia and seminars and conferences from time to time.

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