Alfvén wave in dusty magnetosphere
5.1. INTRODUCTION

In the fourth chapter we have described the generation of Alfven wave in the presence of electron beam at substorm times. In this chapter, particle aspect approach is extended for Alfven waves in dusty magnetosphere. Dispersion relation and associated field-aligned currents are evaluated for Alfven wave in a warm, magnetized dusty plasma, consisting of electrons, ions and charged dust particles.

Recently, there is much interest in the study of dusty plasmas following their increased observations in planetary rings, asteroid zones, cometary tails and the earth's lower ionospheric regions (e.g., Whipple et al.; 1985; de Angelis et al., 1988; Goertz, 1989; Gendrin, 1991; Kurth, 1991) as well as in laboratory device (e.g., Sheehan et al., 1990; Garscadden, 1991; Carlile et al., 1991). 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 (e.g., Rao, 1993). 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 (e.g., Allen, 1992; Barnes et al., 1992). 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 (e.g., Varma et al., 1993; Melandso et al., 1993; Rao and Shukla, 1994).
Generally, dust particles in plasma are charged by plasma current, photo-emission, and field emission, etc. (e.g., Draine and Salpeter, 1979). 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 (e.g., Varma et al., 1993). 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 (Das et al., 1996).

The collective effects due to dust did not receive much attention until well into the 1980’s, but it was early realized that a collection of charged dust in a plasma would influence the overall charge balance in the plasma, for example, in flames, and in rocket exhaust (e.g., Sodha and Guha, 1971) in dense interstellar molecular clouds (e.g., Umebayashi and Nakano, 1980) and in planetary magnetospheres (e.g., Morfill, 1983; Goertz and Ip, 1984; Havnes et al., 1984). Previously plasmas with constant (on characteristic time scales of the processes under consideration) charges on the dust particles had been studied extensively. However, recently (e.g., Tsytovich and Havens et al., 1993) the effect of variable charges on the dust particles has been investigated and the influence is found to be strong, especially for low frequency waves.

Waves in dusty plasmas have been studied theoretically by a number of workers, beginning with the work of Blokh and Yarashenko (1985), dealing with waves in Saturn’s rings. Among more recent contributions are those of de Angelis et al. (1998), Rao et al. (1990), D’Angelo (1990), Melandso et al. (1993), Rosenberg (1993), Chow and Rosenberg (1995).
Experimentally, extremely low frequency waves, involving the grain dynamics, were observed by Chu et al. (1994) and later interpreted by D'Angelo (1995) as dust-acoustic waves. More recently, Barkan et al., 1995) reported the observation of dust-acoustic mode in a dusty plasma in which the negative dust grains were indefinitely “levitated” by the electric fields of a double layer. In both experiments the pressure of the neutral gas was relatively high, up to \(~\)100m Torr.

The Alfven wave is the dominant low frequency transverse mode of magnetized plasma (Baronia and Tiwari, 1998). The Alfven wave propagates along the magnetic field and displays a continuous spectrum even in a bounded plasma (Shrivastava et al., 2001). 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 (Tiwari and Rostoker, 1984; Dwivedi et al., 2001).

In the present chapter we have considered the particle aspect analysis using bi-Maxwellian distribution to investigate the Alfven wave propagation in a warm, magnetized dusty plasma consisting of electrons, ions and charged dust particles. This approach has been adopted for the analysis of Alfven wave (Baronia and Tiwari, 1999, 2001) which is based upon Dawson's theory of Landau damping and was considered by Terashima (1967), Tiwari et al. (1985), Dwivedi et al. (2000, 2001), Shrivastava et al. (2001), to the analysis of electrostatic and electromagnetic instabilities. In the present chapter we consider the effects of different charge concentrations, dust particle density and the ratio of the dust particle to that of the electron and to investigate the dispersion relation and associated field-aligned currents the Alfven wave by using
particle aspect analysis. It is presumed that Alfvén waves are generated in the plasmasheet and travel towards the ionosphere where dust components occur naturally, revealed during the space lab2 mission causing the current system in the auroral acceleration region.

5.2. Basic Trajectory

We consider a three component, warm, magnetized plasma embedded in an static magnetic field $B_0$ (z-direction) in which collisions between particles are neglected. The dusty plasma is composed of electrons, singly charged ions and massive, highly negatively or positively charged dust particles of mass $m_d$ and charge $-Ze$ or $Ze$, where $Z_d$ is the number of charges residing on the dust grain surface and $e$ is the magnitude of electron charge (Shukla et al., 1998). In equilibrium, plasma is quasi-neutral and conservation of a particle number density must always hold (Sarkar et al. 1999). Thus for the negatively charged grains,

$$N_{0e} = N_{0e^+} Z_d N_{0d}$$

where $N_{0j}$ is the equilibrium density of the $j^{th}$ species ($j = e, i, d$ for the electrons, ions and dust, respectively).

We shall discuss the behavior of an Alfvén wave in the dusty plasma of plane polarization in the form; (Baronia and Tiwari, 1998; Shrivastava et al., 2001)

$$k \parallel B_0 \quad , \quad k.B = 0 \quad , \quad k = (0,0,k_\parallel) \quad \text{and} \quad E = (E_x, 0, 0)$$

$$E_x = E_1 \cos (k_\parallel z - \omega t)$$
\[ B_y = \frac{E_1 k_{||} c}{\omega} \cos (k_{||} z - \omega t) \quad \text{(5.4)} \]

where \( E_x \) and \( B_y \) are the electric and magnetic fields of the wave. Here, the frequency \( \omega \) is assumed to be real and the amplitude \( E_1 \) is treated as the slowly varying function of \( t \). \( c \) is the velocity of light.

\[
\frac{1}{E_1} \frac{dE_1}{dt} \ll \omega
\]

We consider the plasma consisting of resonant and nonresonant particles, the wave is assumed to start at \( t = 0 \) when resonant particles are not yet disturbed. We begin with the equation of motion for the particles as

\[
m \frac{dv}{dt} = q \left[ E_1 + \frac{v \times (B_0 + B_y \hat{y})}{c} \right] \quad \text{(5.5)}
\]

where \( q \) is the charge and \( m \) is the mass of the particle. \( \hat{y} \) is the unit vector along the \( y \) direction.

Here \( v \) can be expressed as a sum of the unperturbed velocity \( V \) and the perturbed velocity \( u \), i.e. \( v = V + u \), \( u \) is determined by the following set of equations (Shrivastava et al. 2001).

\[
\frac{du}{dt} + i\Omega u = \left[ V_{||} k_{||} \frac{q}{m} \right] E_1 \cos (k_{||} z - \omega t),
\]

\[
\frac{du}{dt} = V_{\perp} \cos (\theta - \Omega t) \cos (k_{||} z - \omega t) \quad \text{(5.6)}
\]
where $u_+ = u_x + iu_y$ and $\Omega = qBo / mc$

Here $E_1$ and $B_y$ are slowly varying quantities and $u_x, u_y$ are the perturbed velocities in the $x$ and $y$ directions respectively. Our method follows that of Terashima (1967), Baronia and Tiwari (1998). The detailed calculations of charged particle trajectories and perturbed density of resonant and non-resonant particles are performed by Shrivastava et al. (2001), which are written as:

\[
\begin{align*}
q & \quad V_{\parallel} k_{\parallel} \quad \Lambda_0 \\
\frac{\delta}{2(\Lambda_0 - \Omega)} & - \frac{\sin (k_{\parallel} z - \omega t - \Lambda_0 t + \Omega t)}{2(\Lambda_0 - \Omega)} - \frac{\delta}{2(\Lambda_0 + \Omega)} \\
\frac{\delta}{2(\Lambda_0 - \Omega)} & - \frac{\sin (k_{\parallel} z - \omega t - \Lambda_0 t - \Omega t)}{2(\Lambda_0 + \Omega)} \\
\frac{\delta}{2(\Lambda_0 - \Omega)} & - \frac{\cos (k_{\parallel} z - \omega t - \Lambda_0 t + \Omega t)}{2(\Lambda_0 + \Omega)} + \frac{\delta}{2(\Lambda_0 - \Omega)} \\
\frac{\delta}{2(\Lambda_0 - \Omega)} & - \frac{\cos (k_{\parallel} z - \omega t - \Lambda_0 t - \Omega t)}{2(\Lambda_0 + \Omega)} \\
\frac{\delta}{2(\Lambda_0 - \Omega)} & - \frac{\sin (k_{\parallel} z - \omega t + \theta - \Omega t)}{2(\Lambda_0 - \Omega)} \\
\frac{\delta}{2(\Lambda_0 - \Omega)} & - \frac{\sin (k_{\parallel} z - \omega t - \Lambda_0 t + \theta)}{2(\Lambda_0 + \Omega)} \\
\frac{\delta}{2(\Lambda_0 - \Omega)} & - \frac{\sin (k_{\parallel} z - \omega t - \Lambda_0 t - \theta)}{2(\Lambda_0 + \Omega)} \\
\end{align*}
\]

\[\text{...(5.7)}\]
\[ n_1(r,t,V) = \frac{q V_{\perp} E_1 k_{||}^2 N(V)}{2 m_0} \frac{1}{(\Omega_0 - \Omega)^2} \left[ \sin(k_{||} z - \omega t + \theta - \Omega t) + \frac{1}{(\Lambda_0 + \Omega)^2} \sin(k_{||} z - \omega t - \theta + \Omega t) \right] \]

...(5.8)

Similarly, for the resonant particles

\[ n_1(r,t,V) = \frac{q V_{\perp} E_1 k_{||}^2 N(V)}{2 m_0} \frac{1}{(\Omega_0 - \Omega)^2} \left[ \sin(k_{||} z - \omega t + \theta - \Omega t) \right] + \frac{1}{(\Lambda_0 + \Omega)^2} \sin(k_{||} z - \omega t - \Lambda_0 t + \theta) \]

\[ + \frac{1}{(\Lambda_0 - \Omega)^2} \sin(k_{||} z - \omega t - \Lambda_0 t - \theta) - \frac{1}{(\Lambda_0 - \Omega)^2} \sin(k_{||} z - \omega t + \Lambda_0 t + \theta) \]

\[ - \frac{1}{(\Lambda_0 + \Omega)^2} \sin(k_{||} z - \omega t - \Lambda_0 t - \theta) \]

\[ + \frac{1}{(\Lambda_0 - \Omega)^2} \cos(k_{||} z - \omega t + \Lambda_0 t + \theta) \]

\[ - \frac{1}{(\Lambda_0 + \Omega)^2} \cos(k_{||} z - \omega t - \Lambda_0 t - \theta) \]

...(5.9)

where \( q = +e \) for ions, \( q = -e \) for electrons, \( q = -Ze e \) for negatively charged dust grains and \( q = Ze e \) for positively charged dust grains.

we take \( \delta = 0 \) for the non-resonant particles and \( \delta = 1 \) for resonant one and

\[ \Lambda_0 = V_{||} k_{||} - \omega, \quad a_0^2 = \Lambda_0^2 - \Omega^2 \]

...(5.10)

Here, \( V_{||} k_{||} - \omega = 0 \) shows the resonant particle condition (Baronia and Tiwari, 1998). The resonant particle trajectories may be used to evaluate the growth rate and charged particle heating by Alfvén wave with the help of energy exchange method.
The dispersion relation and current are evaluated by taking the zeroth order distribution (Dwivedi et al., 2000, 2001), \( N(V) \) of the form

\[
N(V) = N_0 f_{\perp j}(V_{\perp}) f_{\parallel j}(V_{\parallel})
\]

\[\begin{align*}
f_{\perp j}(V_{\perp}) &= \left[ \frac{\sqrt{2\pi} \sigma_{\perp}}{mV_{\perp}} \right] \exp\left\{ -\frac{mV_{\perp}^2}{2\sigma_{\perp}^2} \right\} \\
f_{\parallel j}(V_{\parallel}) &= \left[ \frac{\sqrt{2\pi} \sigma_{\parallel}}{mV_{\parallel}} \right] \exp\left\{ -\frac{m(V_{\parallel} - V_0)^2}{2\sigma_{\parallel}^2} \right\}
\end{align*}\]

where \( N_0 \) is the equilibrium density of the \( j \)th species, \( T_{\parallel} \) and \( T_{\perp} \) are the parallel and perpendicular temperatures with respect to the ambient magnetic field, \( V_0 \) is electron beam velocity.

### 5.3. CURRENT

The perturbed current per unit wavelength in the presence of Alfvén wave in dusty plasma is evaluated by using the following set of equations (e.g., Baronia and Tiwari, 1999; Shrivastava et al., 2001; Dwivedi et al., 2001)

\[
J_{\text{led}} = \int_0^L ds \int_0^\infty 2\pi V_{\perp} dV_{\perp} \int_{-\infty}^{\infty} dV_{\parallel} q \left[ (N + n_1)(V + u) - NV \right]_{\text{led}}
\]

and

\[
J_{\text{ed}} = J_e - J_d
\]

\[\cdots(5.12)\]
where \( +J_d \) is for the positively charged dust grains, \(-J_d \) is for the negatively charged dust grains and \( d \) represents the length of magnetic field line elements and \( ks = k_r \).

Thus the total current per unit wavelength flowing along the magnetic field in the presence of Alfven wave in dusty plasma is given as

\[
J_z = \frac{3e k_{||}^2 E_t^2}{8m_e \omega_{pe}^2} \left[ \frac{\omega_{pi}^2 V_{T \perp i}^2}{\Omega_{ci}^4} + \frac{\omega_{pi}^2 V_{T \perp i}^2}{\Omega_{ci}'(m_i/m_e)} + \frac{\omega_{pd}^2 V_{T \perp d}^2}{\Omega_{cd}'(m_d/m_i)} \right] \quad \ldots (5.13)
\]

Where plasma frequency is defined as \( \omega_{pe,d} = (4\pi N_0 q^2/m_{e,d})^{1/2} \) and the perpendicular component of thermal velocity is defined as \( V_{T \perp i} = (2T_{i,e}/m_i)^{1/2} \). Here the temperature \( T \) is expressed in the unit of energy, \( \Omega_{i,e,d} \) is the cyclotron frequency.

### 5.4 Dispersion Relation

To evaluate the dispersion relation in the presence of plane polarized Alfven wave we use the wave equation in the following form (e.g., Baronia and Tiwari, 1998; Shrivastava et al., 2001)

\[
\frac{\partial^2 E_x}{\partial z^2} = \frac{4\pi}{c^2} \frac{\partial J_x}{\partial t} + \frac{1}{c^2} \frac{\partial^2 E_x}{\partial t^2} \quad \ldots (5.14)
\]

Substituting the value of \( J_x \) in terms of perturbed velocity \( u_x \) and perturbed density \( n_1 \), the dispersion relation for Alfven wave in warm, magnetized dusty is evaluated as
\[ \omega = k_{\parallel} V_A \left[ \frac{m_i}{m_d} \frac{N_0}{Z_d N_{0d}} \right]^{1/2} \left[ 1 - \left( \frac{m_i}{m_e} \right) \frac{V_{T_{\parallel j}}}{V_A^2} + \frac{(V_{\parallel i}^2 + V_0^2)}{V^2} \left( \frac{m_i}{m_d} \right) \frac{N_0}{N_{0d}} \right]^{1/2} \]}

where thermal velocities along the magnetic fields are defined as \( V_{T_{\parallel j}} = (T_{\parallel j}/m_i)^{1/2} \)
and \( V_A = B_0 / (4\pi N_0 m_i)^{1/2} \) is the Alfven wave speed. It is noticed that the dispersion relation is modified due to thermal effects of ions, electrons, dust grains and electron beam velocity \( V_0 \). In case the thermal effects and electron beam velocity vanish the dispersion relation reduces to well known form of cold plasma, \( \omega = k_{\parallel} V_A \).

5.5. RESULTS AND DISCUSSION

In the numerical evaluation of the dispersion relation and associated current per unit wavelength, we have used the following plasma parameters suitable for the earth’s magnetosphere (specially for auroral acceleration region) (e.g., Tiwari and Rostoker, 1984; Das et al., 1996).

- \( B_0 = 4300 \text{nT} \)
- \( \Omega_i = 412 \text{ S}^{-1} \)
- \( \Omega_d = 6.8 \times 10^{-10} Z_d \text{ S}^{-1} \)
- \( N_{0i} = N_{0e} = 10 / \text{m}^3 \)
- \( m_d = 10^{-15} \text{ kg} \)
- \( \omega_{pi} / \Omega_i = 10 \)
- \( K_{T_{\parallel i}} = 100 \text{ eV} \)
- \( K_{T_{\parallel e}} = 100 \text{ eV} \)
- \( E_1 = 50 \text{ mV} / \text{m} \)
- \( V_{T_{\parallel i}} = 3.5 \times 10^4 \text{ m/s} \)

The earth’s magnetosphere is abundant with dust particles originating from collisional fragmentation of debris from comets, industrial contaminations etc., creating an environment for dusty plasmas. The formation of Alfven wave is possible by field line resonances or the electron beam at substorm times in the earth’s plasma-sheet region, propagating towards the ionosphere causing field-aligned current and closure current and the auroral acceleration (e.g., Tiwari and Rostoker, 1984).
In the present analysis the expressions for frequency and associated field-aligned current per unit wavelength are numerically evaluated in magnetospheric dusty plasma in the presence of different charge concentrations, dust particle density including the ratio of the temperature of the dust particle to that of electron. The results are presented in figures 5.1-5.9.

Figure 5.1 predicts the variation of Alfven wave frequency $\omega$ with $k_\parallel$ for different values of charge concentration $Z_d$ at the fixed values of $N_0d$ and $T_d/T_e$ for the both, negatively and positively charged dust grains. The frequency $\omega$ increases with the wave number $k_\parallel$ as the basic characteristic of Alfven wave propagation in cold plasma; however, it is modified by the thermal effects. It is observed that wave frequency $\omega$ is decreased with the increase of charge concentration on dust grains. Since the dust particles containing higher charges are more affected by the electromagnetic field of the wave due to greater force, and due to higher mass the frequency is decreased in the presence of dust grains. Hence it will support the lower frequency Alfven waves proportional to the quantity of charge on dust grain indicated by $Z_d$. The frequency is independent of the sign of charge on dust grains.

Figures 5.2 and 5.3 show the variation of field-aligned currents per unit wavelength with $k_\parallel$ for different values charge concentrations for positively ($Z_d>1$) and negatively ($Z_d<1$) charged dust grains respectively. Since the current is directly proportional to the amount of charge flowing, the current is increased with the increase of charge concentrations. The effect of positive charge concentration is to increase the downward current and the negative charge concentration to increase the upward parallel
$N_d = 1 \times 10^{-5}\, \text{cm}^3$

$\dfrac{T_d}{T_e} = 8 \times 10^{-2}$

Fig 51: $\omega$ versus $k_{\parallel}$ for different $Z_d$
$N_{od} = 1 \times 10^{-5}/\text{cm}^3$

$\frac{T_d}{T_e} = 8 \times 10^{-2}$

$Z_d = 8 \times 10^4$

$Z_d = 6 \times 10^4$

$Z_d = 4 \times 10^4$

$Z_d = 2 \times 10^4$

Fig. 52: $J_{\|}$ versus $k_{\|}$ for different positive $Z_d$
Fig 53: $J_{\|}$ versus $k_{\|}$ for different negative $Z_d$
current. Thus the field-aligned currents are enhanced when the wave encounters the dusty plasma of the lower auroral ionospheric region. The increase of currents due to higher wave numbers is also observed.

As seen from figure 5.4, the Alfven wave frequency \( \omega \) increases with \( k_{||} \) but decreases with the increase of dust particle density. It means that when the dust particle density is increased, the charge density is also increased. Since the force on the charge particles due to the electric field is proportional to the magnitude of the charge, therefore, the wave electric field exerts more force on the dust particles. The higher charges are carried by higher mass dust particles, therefore, the lower frequency waves are driven due to the lower mobility of the dust particles.

Variation of downward and upward field-aligned currents per unit wavelength with \( k_{||} \) for different values of \( N_{oa} \) and for the positive and negative dust grains, are shown in figures 5.5 and 5.6 respectively. The enhancement of the currents with the increase of \( k_{||} \) as well as \( N_{oa} \) is clearly exhibited. The higher dust particle number density accumulates higher charge density also therefore; the currents are increased with \( N_{oa} \). The direction of the currents depends upon the sign of \( Z_d \).

The thermal effects due to the dust temperature on the variation of Alfven wave frequency with respect to \( k_{||} \) for fixed \( Z_d \) and \( N_{oa} \) is presented in figure 5.7. It is predicted that the enhancement of wave frequency occurs at different \( T_d / T_e \), thus the wave frequency is increased due to the temperature of the dust particles analogous to plasma wave propagating in thermal plasma. Figures 5.8 and 5.9 predict the variation of downward and upward field-aligned current per unit wavelength with respect to \( k_{\parallel} \) for
Fig. 54: $\omega$ versus $k_{\parallel}$ for different Nod
Fig 55: $J_{II}$ versus $k_{II}$ for different $N_{od}$
Fig. 5.6: $J_{\parallel}$ versus $k_{\parallel}$ for different $N_{od}$

$Z_{d} = -8 \times 10^{3}$

$\frac{T_{d}}{T_{e}} = 8 \times 10^{-2}$

$N_{od} = 2 \times 10^{-5}/cm^3$

$N_{od} = 4 \times 10^{-5}/cm^3$

$N_{od} = 6 \times 10^{-5}/cm^3$

$N_{od} = 8 \times 10^{-5}/cm^3$
\[ Z_d = 8 \times 10^3 \]
\[ N_{od} = 1 \times 10^{-5}/\text{cm}^3 \]

\[ \frac{T_d}{T_e} = 10 \times 10^{-4} \]
\[ \frac{T_d}{T_e} = 1.6 \times 10^{-4} \]
\[ \frac{T_d}{T_e} = 1 \times 10^{-4} \]
\[ \frac{T_d}{T_e} = 0.6 \times 10^{-4} \]

Fig 57: \( \omega \) versus \( k_{\|} \) for different \( \frac{T_d}{T_e} \)
Fig. 58: $J_{\parallel}$ versus $k_{\parallel}$ for different $\frac{T_d}{T_e}$
$Z_d = -8 \times 10^3$
$N_{od} = 1 \times 10^{-5}/\text{cm}^3$

Fig. 59: $J_{||}$ versus $k_{||}$ for different $\frac{T_d}{T_e}$
different \( T_d / T_e \) at fixed \( Z_d \) and \( N_{0d} \). The downward current decreases due to thermal agitation and the upward current is diverted towards downward current at higher \( T_d / T_e \). This may be due to electric field of the Alfvén wave.

In past, Alfvén wave model has been presented to explain field-aligned currents and auroral acceleration at the sub storm events (e.g., Goertz, 1979, 1984; Tiwari and Rostoker, 1984). It is presented that Alfvén waves are generated in the plasma-sheet region of the earth’s magnetosphere either by surface waves or field-aligned resonances and propagate toward the ionosphere exhibiting auroral phenomena. The present chapter predicts that the dispersion relation and field-aligned currents are affected by the dusty plasma. The wave reaches to the lower ionosphere; the field-aligned currents are modified due to density, charged concentration and the temperature of the dust grains. The wave frequency is also lowered due to dust parameters as discussed. Our present chapter also helps us to understand the filamentary structures existing within the diffuse aurora if the plasma is taken to be abundant with dusty plasma. That aurora is a part of the over all interactions of the solar wind, the earth’s magnetosphere and the earth’s atmospheric particles. The energy loaded in the magnetotail may be driven by the Alfvén wave causing aurora. When these spectacular displays of luminous radiation (auroras) in arctic skies are examined carefully, some clear microscopic patterns such as the discrete arcs having certain shapes with spacings of a few tens of kilometers, are observed which may be explained by the Alfvén wave model in the dusty plasma.

Alfvén wave model in the dusty plasma proposed by us in the present chapter may be relevant to outer space as well as laboratory plasmas for Alfvén wave heating. Auxiliary heating by means of Alfvén waves has been tried in some laboratories.
Alfven waves have recently been proposed for space resolved measurement of magnetic fields in tokamaks and may become important as a diagnostic tool in future (e.g., Das et al. 1996).

5.6. SUMMARY

Dispersion relation and associated field-aligned currents are evaluated for Alfven wave with bi-Maxwellian distribution function using particle aspect approach in a warm, magnetized dusty plasma, consisting of electrons, ions and charged dust particles. Effects of different charge concentrations, dust particle 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 wave, however, the temperature of 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 magnetosphere- ionosphere coupling.