CHAPTER I

1.1. INTRODUCTORY REMARKS.

The contents of this thesis are arranged under five chapters. Chapter - I is of review nature and deals with a general intoroduction to the thesis. Chapter II is devoted to the study of wave propagation in a plasma filled elliptical waveguide. It consists of three sections, In the first Section of this chapter propagation of electromagnetic waves in cold plasma filled elliptical waveguide is discussed and rate of energy flow through the waveguide is calculated in terms of Mathieu functions. In the second section, nature of space charge waves in an elliptic plasma column in the presence of finite and infinite axial magnetic field is discussed while in the third section propagation of electromagnetic waves in warm plasma filled elliptical waveguide is discussed.

Chapter III is concerned with the propagation of waves in a warm plasma filled cylindrical wageguide. This chapter comprises two sections. In the first section, the disperssion relations for perfectly conducting wageguides in the presence of finite and infinite magnetic field are derived while in the second section propagation of waves inside a cylindrical waveguide partially filled with warm plasma is considered.

Chapter IV is devoted to the study of propagation waves in a warm plasma between two perfectly conducting plates. This chapter comprises two sections. In the first section propagation of electromagnetic waves in a warm plasma filled parallel plane waveguide and in a prallel plane waveguide pertially filled with warm plasma is discussed. In the second section propagation of waves in a warm plasma filled parallel plate waveguide with one boundary corrugated is discussed.

The last chapter is devoted to derive the dispersion relation for wavr propagation through two-temperature plasma using two-fluid model hydrodynamic equations and several excitation conditions are deduced.

Before we discuss various problems we present below a brief survey of literature on wave propagation through plasma filled cylindrical, parallel plate elliptical waveguides. Also a brief survey of literature on wave propagation through two-temperature plasma is given below.

1.2. A SHORT REVIEW OF EARLIER WORKS ON WAVE PROPAGATION THROUGH BOUNDED HOMOGENEOUS PLASMA AND TWO - TEMPERATURE PLASMA.

A study of wave propagation in plasma filled waveguide is of great importance in ionospheric investigations, plasma diagnostics and fusion has attracted the attention of various researchers in past years. A brief review of propagation of waves in plasma filled waveguide are given below:

Hahn (1938) has shown that the basic characteristics of a new type of vacuum tube, using a velocity modulated electron beam may be explained by means of wave propagating along the beam. For an ideal tube in which the beam was assumed to be of uniform density throughout its length he described the small amplitude slow "Space Charge" waves which have axial symmetry. Ramo (1938) studied for general slow space charge waves which do not necessarily posses symmetry about the axis. Schumann (1956) discussed the nature of wave propagation in a plasma between two infinite conducting planes and established that there are three frequency ranges in which propagation constant was imaginary and if plasma moves in the direction of an applied magnetic field, the excitation of electromagnetic waves in these ranges appeared possible. The natural modes of oscillation of a cylindrical plasma was considered by Stix (1957). To derive the dispersion relation he followed normal mode analysis similar to that of Kruskal and Schwarzshild (1954) and deduced that frequency well below the electron plasma and electron cyclotron frequency, there appeared in two limiting cases hydromagnetic waves and waves whose natural frequencies were close to the ion cyclotron frequency. Korper (1957) deduced the oscillation of plasma cylinder of infinite length and established that there were two types of oscillation. Dawson and Oberman (1959) deduced the properties of the normal modes of a cold plasmas slab and cylinder, situated in a strong magnetic field and then used to discuss the transmission and reflection of radiation the scattering by a plasma cylinder, the responce to deriving sources in the vicinity of the plasma and the radiation due to plasma oscillation. Trivelpiece and Gould (1959) investigated the properties of space charge waves by regarding the plasma as a dielectric and solving the resulting field equations. They considered the effect of steady axial magnetic field but the motion of heavy ions and electron temperature effects were neglected. Waves were found to exist at frequencies low compaired with the plasma frequency as well as waves with oppositely directed phase velocity and group velocities. Camus and Mezec (1962) studied the propagation of waves in a circular plasma filled waveguide with magnetic field directed along the axis neglecting collision, thermal motion and ion movements. The dispersion relation for slow waves and cut-off frequencies were deduced. Hall (1963) considered parallel plate plasma problem under the assumption of uniform density and specular boundary conditions at the plates. Sayakhov (1964) deduced that the amplitude and period of the space charge and electron velocity waves were decreasing function of the radial velocity. Anderson and Weissglas (1966) considered the propagation of ion acoustic waves along a cylindrical plasma and established that in addition to the infinite number of ion wave modes there exists a surface mode which was the ion equivalent of the electron surface mode of Trivelpiece and Gould (1959). Wong (1966) in a theoretical analysis showed that the boundary effects on ion acoustic waves propagating along the magnetic field to be unimportant if the ion Larmor radius is much smaller than the plasma radius. Kondratenko (1967), Kitsenko and Shoucri (1968) and Guernsey (1969) discussed propagation of waves in bounded plasma. Karplyuk and Kolesnichenko (1970) investigated propagation of slow high-frequency waves in the presence of a magnetic field in a cylindrical plasma waveguide surrounded by a dielectric or metal. They analysed the dispersion relation numerically and established that allowance of temperature leads to the appearance of new branches in confined plasma system.

Waite (1968) devised to apply the effect of electron temperature to Maxwell's equations by the treatment of hydromagnetics (compressible plasma theory). Using compressible plasma theory Ito et al (1971) showed that the waves consisting of electron sound wave mode and electromagnetic wave mode are able to travel in the plasma waveguide. Azakami et al (1972), used same method to the waveguides and established that in case of parallel waveguide the waves can be separated into TM- and TE- modes and in case of circular waveguide the waves can be separated only at r = 0 mode. Zhelyazkov and Nenovski (1973) derived the dispersion equation of ion surface waves propagating along a warm plasma layer bounded by dielectrics or along a dielectric. They deduced that in case of a plasma layer bounded by dielectrics the propagation of two types of ion surface waves [one with frequency $\omega > \omega_{pi}/(1+\epsilon)^{1/2}$, and another with a frequency $\omega < \omega_{pi}(1+\epsilon)^{1/2}$] was possible , in the case of a dielectric layer bounded by warm plasmas both corresponding waves had frequencies lower than $\omega_{pi}/(1+\epsilon)^{1/2}$. Van Den Berg et al. (1973) and Dwar et al.(1974) studied wave propagation in elliptical waveguide. Kondratenko et al.(1974) theoretically analysed the propagation of low frequency waves in a cylindrical waveguide filled with a highly nonisothermal plasma.Weber (1975) obtained the dispersion relation for the propagation of electromagnetic waves parallel to a magnetic field in a cold plasma between conducting planes and its numerical computation yields six types of waves.

The first attemped to build up a Kinetic theory of the surface waves in a cylindrical hot plasma was made by Kondratenko (1972). Atanassov et al (1976) derived the dispersion relation of the axially symmetric surface waves propagating along a hot plasma column by solving Vlasov and Maxwell's equations. Shivarova (1977) determined the dispersion of the high frequency surface waves existing in a cylindrical plasma column surrounded by a dielectric in the entire electromagnetic region of their propagation, on the basis of a hydrodynamic description of cold collisional current carrying plasma Shivarova (1978) in his another research work obtained the propagation of high frequency axially symmetric surface waves along a current carrying hot plasma column in a gloss tube by means of a kinetic plasma model. The wave spectrum and the damping rate were also obtained. Shivarova et al. (1978, 1979) studied the physical as well as the spectra and damping rates of high and low frequency surface waves in semi-infinite and cylindrical plasma. The dispersion relation of surface waves propagating on a homogeneous Maxwellian plasma column with sharp boundary and surrunded by dielectric and vacuum were also obtained. Phalswal et al.(1979, 1980) in series of research paper considered the wave propagation in a plasma filled waveguide. Cibin (1980) discussed analytically the effect of losses on the dispersion relation of guided electron plasma waves on a plasma cylinder. Arora (1982) discussed the collisional effects on the TM- modes in the plasma filled parallel plane wave guide. Zholyazkev (1983), Unz (1983) and

Peneva et al.(1983) discussed various problems on wave propagation in plasma filled wave guide. Das and Basu (1984) studied the propagation of intermediate frequency waves in a plasma column magnetized axially and enclosed in a conducting cylinder. Khan (1984) investigated the propagation of plane plasma waves through a collisional plasma sphere. Zhilai (1985) derived eigen modes of the fast magneto fluid waves and slow waves for a plasma filled waveguide with elliptical cross-section and showed that fast waves can propagate in a high density region, while slow waves propagate only in the region of low plasma density. Cross and Murphy (1986) derived the dispersion relation for Alfvén surface waves in a cylindrical plasma assuming that the plasma was separated from a conducting wall by a region of low density plasma. Prasad et al.(1987) derived the electromagnetic wave propagation in a parall plate waveguide with one boundary corrugated and filled with unaxial warm drifting plasma. They established that the fast and the slow waves are greately effected by temperature and the drift velocity, where as the waveguide wave insignificantly effected.

Now We discuss the short review work of the two-temperature plasma. Yakimenko (1962) discussed the oscillation of a cold uniform plasma cylinder containing electrons and two ion species in a uniform magnetic field parallel to the cylinder axis. A dispersion relation was obtained for propagation at an arbitrary angle with respect to the magnetic field. Aliev and Silin (1965) studied the effect of external periodic electric field on electrostatic waves in a cold plasma in which the wave vectors of the excited waves had non-vanishing components along the direction of the applied electric field. Montgomery and Alexeff (1966) studied the possibility of parametric excitation of transverse electromagnetic waves by external periodic electric field and they pointed out the importance of such a study in connection with the energy loss during the turbulent heating of a plasma, due to excitation of transverse waves that is free to leave the plasma. Prasad (1967, 1968) and Nishikawa (1968) discussed the effect of spatially uniform external periodic electric field on wave propagation through a plasma. Das (1970) starting from the two fluid model hydrodynamic equations, a dispersion relation was obtained for wave propagation through a two-temperature plasma perpendicular to the direction of an external electric field and several excitation conditions are deduced. Das (1970) deduced the possibility of excitation of extra-ordinary waves in a cold plasma by small and periodic external electric field. Several excitation conditions and maximum growth rate were deduced. Das (1971, 1975) derived the dispersion relation for wave propagation through a hot electron plasma perpendicular and parallel to a spatially uniform external periodic magnetic field and several excitation conditions were derived.

1.3. SHORT CRITICAL SURVEY OF THE RESULTS OF PRESENT INVESTIGATIONS.

In this section we discuss the motivation of the present thesis. Here also the original and significant points of the methods of our investigation are reported briefly. The results of the present thesis which we claim to be new are briefly reviewed here.

In chapter II, propagation of waves in plasma-filled elliptical waveguide has been discussed. In section one Magnetodydrodynamic equations are used to solve the problem.

Mathieu functions and modified Mathieu functions are used to calculate the dispersion relations. The electromagnetic field components in elliptic coordinates are derived interms of Mathieu functions. We see though electromagnetic field components in plasma-filled elliptical waveguide are different those of empty elliptical waveguide Chu (1938), electric and magnetic lines of froce are same in both the cases. In elliptical waveguides, propagation can not be possible in absence of the components E_μ and B_θ but the vanishing of E_μ and B_θ does not effects the propagation in circular waveguide. To calculate the pulsatances of the modes the dispersion relations are derived for even and odd solutions. The time rate of energy flow through the elliptical waveguide in the direction of wave propagation is obtained. In the limiting process, dispersion relations for wave propagation in circular waveguide have been deduced and it is interesting to note that this dispersion relation represents both even and odd solutions of elliptical waveguide. In section two, the nature of space-charge waves of an elliptical plasma column in the presence of finite and infinite constant axial magnetic field are studied. Maxwell's equations for the perturbed variables in terms of dielectric tensor ϵ are taken to solve the problem. From the dispersion relation (infinite axial magnetic field) we see empty waveguide cut-off frequency $\omega_o = 2p_{2m,\nu}/a\sqrt{\epsilon_o}$ andthe plasma cut-off frequency is $\omega = [\omega_p^2 + 4p_{2m,\nu}^2/(a^2\epsilon_o)]^{1/2}$ i.e., the plasma-filled waveguide mode cut-off frequency is shifted upwards as in case of circular waveguide. From the graphical representation of dispersion relation it is clear that the upper pass-band represents waveguide modes and the lower pass-band between $\omega = 0$ and $\omega = \omega_p$ represents plasma oscillation. The dispersion relation for finite axial magnetic field is derived. The graphical representation of the dispersion relation for a strong magnetic field ($\omega_c > \omega_p$) and for a weak magnetic field ($\omega_c < \omega_p$) are shown. For the case $\omega_c > \omega_p$, in addition to the mode ($\omega < \omega_p$), the upper hybrid mode $\omega_c < \omega < (\omega_p^2 + \omega_c^2)^{1/2}$ appear as a characteristic frequency in the plasma. This mode has the interesting feature that it is a backward wave. As the magnetic field is further reduced ($\omega_p > \omega_c$), it is seen that waves propagate for frequency less than the cyclotron frequency. The backward wave mode now propagates in the frequency range $\omega_p < \omega < (\omega_p^2 + \omega_c^2)^{1/2}$. Here we see ~~plasma filled we see~~ plasma filled waveguide without an external magnetic field will not propagate space-charge waves. Lastly, the dispersion relation for a plasma-filled cylindrical waveguide in presence of finite and infinite axial magnetic field are derived as a limiting case. In section three, electromagnetic field components and electron velocity in warm plasma filled elliptical waveguide are derived. Here we see that the waves combining the electron sound wave mode with electromagnetic wave mode can propagate in elliptical waveguide containing the warm plasma. The waves can be separated into TM- modes and TE- modes only at $r = 0$ mode and other modes became hybrid modes. These results cannot be explained upto the present by the cold plasma approximation power transmitted in the direction of wave propagation for TE- and TM- modes are calculated and lastly dispersion relation in circular waveguide have been derived with the usual limiting process.

In chapter III, the infulence of temperature on the propagation of waves in a cylindrical waveguide is considered by using compressible plasma theory. In section one applying compressible plasma theory we try to include the finite temperature effects on the Trivelpiece and Gould (1959) problem. The dispersion relations for perfectly conducting waveguides in the presence of finite and infinite magnetic field are derived. In case of finite magnetic field, the waves cannot be separated into TE- and TM- modes. The dispersion curves for a warm plasma-filled waveguide in a zero magnetic field are shown graphically. Here we see that for small values of ω ($\omega<\omega_p$) there is only one dispersion curve but for large values of ω ($\omega>\omega_p$) there are infinite number of dispersion curves. The dispersion curves for small magnetic field are also shown graphically. Here we see that for large values of ω ($\omega>\omega_p$) the frequency shifts are negative and the magnitude of the frequency shift increases with the wave number, whereas for small values of ω ($\omega<\omega_p$) the frequency shifts are positive and the magnitude of the frequency shift decreases as the wave number increases. Lastly, the dispersion relation for an infinite axial magnetic field are shown graphically. The upper pass-band

represents the waveguide modes and the lower one represents
plasma oscillation. In section two, the dispersion relation for a perfectly conducting waveguide, filled with warm plasma immersed in a vacuum cylinder, in the presence of a finite magnetic field are derived. Here we see that the waves cannot be separated into TE- and TM- modes. As a particular case, the dispersion relations for zero magnetic field are derived and different modes of propagation are shown graphically. The graphs of wave propagation for which phase velocity is less than the velocity of light and R_1 (radius of the vacuum cylinder) is very large in comparison to R (radius of the plasma cylinder) i. e., $R_{1/R} \to \infty$, for various values of $R\omega_{p/c}$. are shown graphically. The nature of wave propagation for $R_1 = 2R$ are also shown graphically for various values of $R\omega_{p/c}$.

In chapter IV, we consider the propagation of waves in a warm plasma filled perfectly conducting plates. To include the temperature effects, compressible plasma theory is also used here. In section one, the dispersion relation for the propagation of waves in a parallel plane waveguide filled with warm plasma are derived. It is found that the waves cannot be separated into sound wave mode and electromagnetic wave mode. Neither can they be separated into TE- modes and TM- modes. They appear as a hybrid modes. But in absence of external magnetic field we see that electric field are separated into the electron sound wave mode and the electromagnetic wave mode and also magnetic field has no connection with the electron sound wave mode. The waves can be separated into TM- modes and TE- modes as with the cold plasma approximation. Next, we apply compressible plasma theory to derive the dispersion relation for wave propagation between two conducting planes with a magnetized plasma resting on one plane and a vacuum gap between the plasma and the other. In section two, we discuss the wave propagation in a warm plasma between two conducting plates of which one plate is plane and the other is corrugated. The dispersion relations for TE- modes and TM- modes are derived in absence of external magnetic field. In case of TE- modes we see that the dispersion relation is independent of temperature but depends on the z. Therefore, the dispersion relation also valid for cold plasma filled waveguide whose lower boundary is a plane conducting plate and the upper boundary is corrugated. The dispersion relation for the TM- modes expresses the fact that the wave number k depends upon the frequency ω as well as distance z in the manner which is determined by the form of roots of these equations. As the wavelength of the periodic surface approaches to infinity or the amplitude of the surface tends to zero the above dispersion relation coincides with that of warm plasma filled parallel plate waveguide Azakami et al. (1972).

In chapter V, starting from the two-fluid model hydrodynamic equations, dispersion relation is obtained for wave propagation through a two-temperature plasma. The effect of a spatially uniform external periodic magnetic field on wave propagation through a hot plasma was considered. A dispersion relation is obtained keeping terms upto ϵ^2, ($\epsilon^2 = \Omega_o^2/\omega_o^2$, $\Omega_o = eB_o/cm_e$). For small values of ϵ the transverse wave, longitudinal wave and acoustic wave propagate with the shifted frequency. Excitation of the waves is found to be possible when the frequency of the external magnetic field satisfies any one of the following conditions

$$\frac{\Omega_k}{\omega_o}, \frac{\omega_L}{\omega_o}, \frac{\omega_A}{\omega_o} \simeq n \text{ or } n + \frac{1}{2},$$

$$\frac{\Omega_k \pm \omega_L}{\omega_o}, \frac{\Omega_k \pm \omega_A}{\omega_o}, \frac{\omega_L \pm \omega_A}{\omega_o} \simeq n,$$

when Ω_k, ω_L and ω_A denote the frequcies of the transverse, longitudinal and acoustic waves and n is any positive integer.

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