ABSTRACT

This thesis has been prepared out of the studies of nonlinear waves in plasma under different physical situations. The main objective of the investigation is to explore the possibilities of the formation of Solitary waves within the context of different theoretical plasma models. Mathematically, the plasma models are considered in the feasible domains available either in laboratories or in stellar plasmas.

The first chapter deals with an introduction narrating the innovative investigations of plasma research (both theoretical and experimental) in the modern days all over the world. Recent setup in experimental device, used in the generation as well as confinement of plasma in different cases is depicted. Some of the multitude of methods used successfully in the field of wavelike phenomena has also been mentioned. Specific mathematical tools (such as standard equations) considered, in connection with plasma waves and instabilities are explained for continuance of the subsequent chapters.

The remaining chapters have been devoted to specific investigation of elaborate mathematical and physical plasma situations, that lead to conclusions which often match with experimental expositions. The whole work of the thesis is confined to the studies of nonlinear waves in warm and cold collisionless plasma. On the basis of the degree of nonlinearity, two basic modes of plasma waves namely the Kinetic Alfvén mode and the Ion Acoustic mode in the plasma have been incorporated. As such ion acoustic solitary waves (both in warm and cold plasmas) have been studied through the Kortweg- de Vries (KdV) equation, for multispecies plasma. For the kinetic Alfvén solitary waves (both in cold and warm plasmas), we have taken into account of the energy integral with total nonlinearity in the coupling process.

In chapter 2, we have considered a multispecies warm plasma model in one dimension. In this chapter, through calculations over second order quantities with

reference to the small parameter ε ($<< 1$) that stands for the weak nonlinearity of the configuration, the KdV equation is derived in the presence of negative ions of equal temperature in the plasma, with the positive ions. The role of electrons' initial drift velocity (v'_e) along the direction of motion, in the formation of compressive and rarefactive solitary waves in the plasma, is thoroughly investigated. It is observed in the investigation that for weak nonlinearity, the concentration of negative ions plays an effective role, both when Q'($= m_j/m_i$, negative ion to positive ion mass ratio) > 1 and $Q'<1$. Different deterministic values of the parameters α ($= T_i/T_e$, ion to electron temperature ratio, with $T_i = T_j$), r ($= n_{jo}/n_{io}$, negative to positive ion equilibrium number density ratio), and v'_e are mentioned depending upon numerical calculations for the nonlinear coefficient (p) and the dispersion coefficient (q) in the KdV equation maintaining the required balance between p and q for the formation and propagation of solitary waves.

In chapter 3, we have considered the formation of ion acoustic solitons in a cold plasma with electrons' initial drift velocity (v'_e) along the direction of motion having a negative component of ions. The KdV equation has been derived without ion temperature for both the positive and negative species and the corresponding solitary wave solution has been deduced. From numerical calculations, a typical relationship between the density ratio (r) and the mass ratio (Q') has been established in an interesting manner to characterise the formation of solitary waves in the plasma under investigation.

In chapter 4, Kinetic Alfvén solitons (KAS) in a cold plasma have been studied. Opting for the two-fluid model, we have considered the initial drift velocity (v_e) of the electrons moving parallel to the external magnetic field $B_0\hat{z}$ to produce Alfvén waves in a low-β { where $\beta(=8\pi n_0 T/c^2 B_0^{\,2})$, is the ratio of the kinetic pressure to the magnetic pressure } plasma. Nonlinear coupling of the fluid equations for ions and electrons with the Maxwell's equations specifying the magnetic field perturbations is taken into account for the generation of Kinetic Alfvén wave propagation. We have deduced the Sagdeev Potential occurring in the energy integral for the Kinetic Alfvén waves to find the Solitary wave solutions. To signify the small magnetostatic disturbances, we have neglected the displacement current in the Maxwell's equations. Consequently, the ion polarization drift also gets neglected. Compressive and rarefactive Kinetic Alfvén solitons are shown to exist for different values of the parameters v_e', k_z (the direction of wave propagation), β, M (mach number of the wave motion, $A\{= (Q/\beta)$ $(v_e' - Mk_z)^2\}$ involved in the system. Amplitude (N, the maximum variation of density) and the width ($\Delta = N/\sqrt{d}$, d being the depth of the Sagdeev potential) of the solitons are calculated for different values of v_e', k_z, M and A for a fixed value of β.

Chapter 5 is devoted to the study of Kinetic Alfvén Solitons in warm plasma in a low-β situation. On consideration of the pressure gradient term in the ion fluid equation of motion, the effect of the parameter α ($= T_i/T_e$, ion to electron temperature ratio) in the formation of the Kinetic Alfvén Solitons is incorporated. A comparision between the results of this chapter and those of the chapter 4, is attempted from numerical observation. The linear dispersion relations for both cold and warm plasmas of chapter 4 and of chapter 5, are deduced retaining all the finite larmour radius effects greatly in support of the next chapter.

In chapter 6, we have considered the hydromagnetic stability in collisionless low-β plasma. In view of the Kinetic Alfvén wave both in cold and warm plasmas, linear instability has been investigated. We have considered the linear dispersion relations derived in chapters 4 and 5 for the analysis. The transcendental nature of the dispersion relations has been avoided by the use of the fluid models. Therefore, the linear dispersion relations of chapter 4 for cold Kinetic Alfvén waves (KAW) and that of chapter 5 for warm KAW, have been solved numerically by the methods of simple algebraic equations. Calculations of $Im (\omega) > 0$ (where ω is the complex wave frequency), have revealed that the effect of ion temperature α ($= T_i/T_e$) is responsible for substancial difference between growth of linear instabilities of cold plasma wave mode and the warm plasma wave mode. The region of existence for the instabilities is aimed at to explore their growth, subject to appropriate dominating parameters.

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