Low frequency electrostatic waves are studied in magnetised plasmas for conditions where the electron temperature varies with a position direction perpendicular to the magnetic field. We analyse the waves with characteristics within the Landau damping region and ion plasma frequency range where the ion cyclotron frequency is below the ion plasma frequency. A particular feature at low frequencies is the change of some of the linear eigenmodes when the frequency is below the ion cyclotron frequency, while the modes are radiative for higher frequencies. For conditions close to the Landau damping case, the model allows the formation of new type of electrostatic shocks. The results are illustrated by results from a 2-D Particle-In-Cell (PIC) code.

Magnetised plasmas are considered here for conditions where the electron temperature $T_e$ varies in the direction perpendicular to an externally imposed homogeneous magnetic field [6, 3]. Such conditions seem to occur in some laboratory facilities. Here we have assumed the electron cyclotron frequency smaller than the plasma frequency, i.e. $\Omega_e < \Omega_i$. The relevant frequencies are assumed to be so low that the electron Landau damping can be taken to be in local Boltzmann equilibrium at all times. We assume quasi-neutrality, $\omega_0 = \omega_c$. For a linearised fluid model of the present model pressure we define a basic electron distribution of the form

$$\rho = -\frac{\partial u}{\partial t}$$

where $\omega_0$ is the electrostatic potential, related to the relative density perturbations as $\omega_0 = \partial u = \frac{\partial T_e}{\partial T_i}$

$$\frac{1}{\Omega_i} \frac{\partial T_e}{\partial \xi} + \frac{1}{\Omega_i} \frac{\partial T_i}{\partial \xi} - (1 - \frac{1}{\Omega_i} \frac{\partial T_e}{\partial \xi}) T_i = 0$$

for $\xi \neq 1$ and $\Omega_i < \Omega_e$. For $\xi \to 1$, $\omega_0 = \omega_c$, the latter containing also the ion cyclotron waves. The wave properties may be summarised in one parameter, the wave vector and the wave vector itself. For very low frequency $\omega e < \omega_i$, these vectors are almost perpendicular, while they are close to parallel when $\omega e > \Omega_i$. In the limit $\omega e \to \Omega_i$, the dispersion relation reduces to $\frac{1}{\Omega_i} \frac{\partial T_e}{\partial \xi} = \frac{1}{\Omega_i} \frac{\partial T_i}{\partial \xi} - \frac{1}{\Omega_i} \frac{\partial T_e}{\partial \xi} = 0$ containing ion cyclotron waves. When $\omega > \Omega_i$, the Landau damping becomes the dominant term, and the dispersion relation only affect at low frequencies $\omega < \Omega_i$. For $\omega = \Omega_i$, the Landau damping becomes the dominant term, and the dispersion relation only affect at low frequencies $\omega < \Omega_i$. If we now let $T_e = T_i$ and $\omega_0 = \omega_c$ be the transverse direction, we can still Fourier transform with respect to $\xi$ to obtain the dispersion relation. We will not discuss in this paper the dispersive terms which contain the quantities by $\psi$. Normalising frequencies and $\xi$-positions so that $\Omega_i = 1$ and $\xi = 0$, we have

$$\frac{\partial u}{\partial \xi} = -\frac{1}{\Omega_i} \frac{\partial T_e}{\partial \xi} + \frac{1}{\Omega_i} \frac{\partial T_i}{\partial \xi} - \frac{1}{\Omega_i} \frac{\partial T_e}{\partial \xi} = 0$$

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