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Interaction Solutions of the KdV Equation Using Wronskian Formalism

Sabeela Shah[1], W. Masood[1,2], M. Siddiq[2]
[1] Department of Physics, COMSATS University Islamabad, Pakistan, [2] National Center for Physics, Shahdara Road, Islamabad, Pakistan.
e-mail (waqasmas@gmail.com):

We have investigated the nonlinear ion acoustic waves (IAWs) in the presence of electron trapping with Landau quantization (LQ) and finite temperature effects (FET). In the small amplitude approximation limit, we have obtained the Korteweg de Vries (KdV) equation for our model fluid equations. Motivated by the recent research works where the rational solutions of the shallow water equations have been conjectured to have applications in the nonlinear propagation of waves in neutral and charged fluids, we have used the Wronskian formalism in this paper to obtain the rational solutions (RSs) of the KdV equation. We have reported here the first, second, and third-order RSs and also presented a general framework that yields the $¥zeta^{th}$ order RSs of the KdV equation. It has been shown that these solutions are very different in structure from solitary and periodic solutions and admit poles in space and time which can successfully explain the physical situations where the small perturbations can suddenly grow in amplitude and impart massive energy to the system. Furthermore, we have explored LQ and FET effects on the first nonlinear ion acoustic RSs. It has been found that increasing the LQ parameter $¥eta$ and the FET parameter T, (i.e., the smearing effect of the Fermi step function) enhances the spatial scale over which RSs are formed. It has been observed that the increase is more pronounced for the temperature correction effects in comparison to the quantizing magnetic field. We have also explained the concept of moving singularities in the second and third order RSs in detail. Furthermore, we have elucidated the interaction of a stable nonlinear structure i.e., one negaton with these singularities. The interaction shows that, even when subjected to infinite amplitude perturbations, the one negaton retains its characteristic shape following the interaction. Similarly, the singularities also exhibit the remarkable property of shape preservation, underscoring their solitonic nature. The present investigation is the first of its kind in plasmas to the best of our knowledge and may be worthwhile to comprehend the formation of rational solutions and their interaction with stable nonlinear structures (i.e., one negaton) in dense plasmas such as those found in the white dwarfs. We hope that the results presented here would trigger interest in the plasma community to carry out more investigations both in classical and quantum plasmas.