Collective Modes in a Plasma Subjected to an External Perturbation

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The effects of an external electromagnetic field on the physical properties of an unmagnetized plasma are studied within the semi-classical approach. We account for possible photon-plasma interactions to obtain a dispersion relation for the collective modes arising in the system.

The electron wave function is calculated on the assumption of small field perturbation to obtain an implicit expression for the dielectric function. We derive expressions for both the longitudinal and transverse oscillations in the plasma. The longitudinal collective modes of the plasma come about the zeros of the real part of the dielectric function and the results are obtained numerically. To calculate the matrix element, we have to sum over all numbers of photons that may participate in the process, and this poses as a difficult computational problem. However, we were able to perform such a sum over the number of photons involved in the process (m) with simple algorithms in FORTRAN language. Although the sum is truncated, it is more properly accounted for than latest results. Fixating a value for the radiation field frequency ω and amplitude (E), we obtain the dispersion relation for the longitudinal modes, showing a smooth damping of the plasmon frequency with an asymptotic value corresponding to the natural plasma frequency. An exponential-like decay of the frequencies is readily observable from the plot of the plasmon frequency as a function of the external field amplitude.

To analyze the contribution of the photons in the damping and modulation processes, we plot the graphics of the dispersion relation and of the plasmon frequency versus external field amplitude for various numbers of photons interacting with the plasma. We were able to succesfully recreate the known results for no photon interaction by setting m iqual to zero. The case of photon emission and that of photon absortion, corresponding to positive and negative values of m, respectively, are studied separadly. In this framework, an expression for the reactive plasma electrical conductivity is obtained. To complete the analysis, we derive an expression for the imaginary part of the plasmon frequency (Landau term) which may indicate regions of system instability.

References

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