M.Sc. Sem II

MPHYCC - 6

Dr. Shiva Kant Mishra
Dept. of Physics
H. D. Jain College, Ara

Alfven Wave :-

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A transverse magnetohydrodynamic wave travelling in the direction of the magnetic field in a magnetized plasma. The velocity of such waves (The Alfven velocity or speed) is characteristic for a plasma of given properties.

A Alfven wave in a plasma is a low frequency travelling oscillation of the ions and the magnetic field. The ion mass density provides the inertia and the magnetic field line tension provides the restoring force.

The wave propagates in the direction of the magnetic field, although waves exist at oblique incidence and smoothly change into the magnetosonic wave when the propagation is perpendicular to the magnetic field.

The motion of the ions and the perturbation of magnetic field are in the same direction and transverse to the direction of propagation.

Alfven Velocity :-

The low frequency relative permitivity ε of a magnetized plasma in given by

$$\varepsilon = 1 + \frac{c^2 \mu_0 \rho}{B^2}$$

where B is the magnetic field strength, c is the speed of light, μ_0 is the permeability of the vacuum, and the mass density is

$$\rho = \sum_s n_s m_s ,$$

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totalled over all charged plasma particles, each species indexed by s, with ion-number density n_s and individual ionic mass m_s; The sum includes both electrons and ions.

The phase velocity of an electromagnetic wave in such a medium is

$$v = \frac{c}{\sqrt{\epsilon}} = \frac{c}{\sqrt{1+\frac{c^2\mu_0\rho}{B^2}}}$$

or $$v = \frac{v_A}{\sqrt{1+\frac{v_A^2}{c^2}}}$$ Where $v_A = \frac{B}{\sqrt{\mu_0\rho}}$

is the Alfven velocity if $v_A << c$, the $v \approx v_A$. On the other hand, when $v_A \to \infty$ Then $v \to c$. i.e. at high field or low density, the velocity of the Alfven wave approaches the speed of light, and the Alfven wave becomes an ordinary electromagnetic wave.

Neglecting the contribution of the electrons to the mass density and assuming that there is a single ion species, we get.

$$v_A = \frac{B}{\sqrt{\mu_0 n_i m_i}} \text{ in SI}$$

$$v_A = \frac{B}{\sqrt{4\pi n_i m_i}} \text{ in Gauss}$$

$$v_A \approx (2\cdot18 \times 10^{+11}\ cms^{-1})(m_i/m_p)$$

when n_i is the ion number density and m_i is the ion mass.

frequencies, and is called the upper hybrid frequency. The 2nd resonant frequency, ω_{LH}, lies between the electron and ion cyclotron frequencies, and is called the lower hybrid frequency.

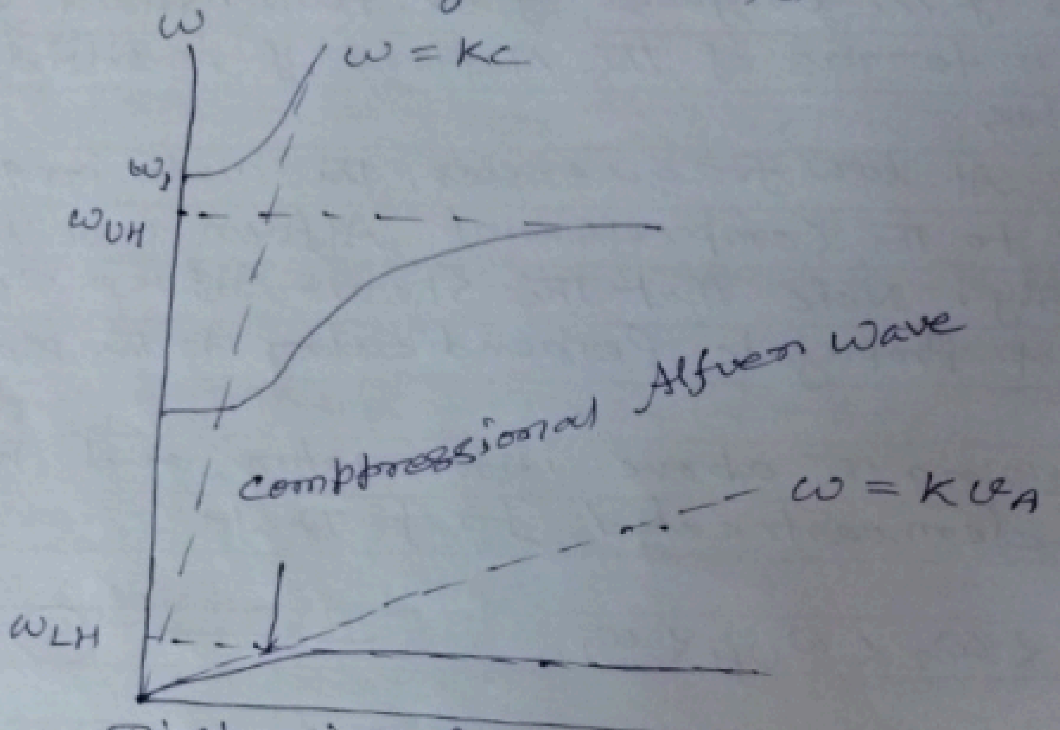
Unfortunately, there is no simple explanation of the origins of the two hybrid resonances in terms of the motions of individual particles.

At low frequencies, the mode in question reverts to the compressional Alfven wave discussed previously. Note that the shear-Alfven wave does not propagate perpendicular to the magnetic field.

Using the above information, and the easily demonstrated fact that

$$\omega_{LH} < \omega_2 < \omega_{UH} < \omega_1 . \quad \text{——— (8)}$$

we can deduce that the dispersion curve for the mode in question takes the form sketched in figure. The lowest frequency branch corresponds to the compressional-Alfven wave. The other two branches constitute the extraordinary, or x^-, wave. The upper branch is basically a linearly polarized electromagnetic wave, somewhat modified by the presence of the plasma. This branch corresponds to a wave which propagates in the absence of an equilibrium magnetic field. The lowest branch corresponds to a wave which does not propagate in the absence of an equilibrium field. Finally, the middle branch corresponds to a wave which converts into an electrostatic plasma wave in the absence of an equilibrium magnetic field.



Dispersion for a wave propagating perpendicular to the magnetic field in a magnetized plasma.

Wave propagation at oblique angles is generally more complicated than propagation parallel or perpendicular to the equilibrium magnetic field, but does not involve any new physical effects.