Plasma as electric medium

$\mu \sim \dfrac{1}{B}$ is not classical magnetics ($\mu \sim B$) (for $\omega \neq 0$ anytime usable $\mu_r = 1$)

$\varepsilon_r \sim ?$ $\quad \vec{D} = \varepsilon_0 \vec{E} + \vec{P} = \varepsilon_0 \overleftrightarrow{\varepsilon}_r \vec{E}$ $\quad \vec{P} = \varepsilon_0 \overleftrightarrow{\chi}_e \vec{E}$ $\quad \overleftrightarrow{\varepsilon}_r = \overleftrightarrow{\delta}_{ij} + \overleftrightarrow{\chi}_e$

In general, medium does not react instantaneously (convolution)

$$\vec{P}(t) = \varepsilon_0 \int_0^{\infty} \overleftrightarrow{\chi}_e(\tau) \vec{E}(t-\tau) d\tau$$

… temporal dispersion

for Fourier image $\vec{P}(\omega) = \varepsilon_0 \overleftrightarrow{\chi}(\omega) \vec{E}(\omega)$ $\quad \vec{D}(\omega) = \varepsilon_0 \overleftrightarrow{\varepsilon}_r(\omega) \vec{E}(\omega)$

Even more generally, medium may react non-locally

$$\vec{P}(t, \vec{r}) = \varepsilon_0 \int \mathrm{d}\vec{r}\,' \int_0^{\infty} \overleftrightarrow{\chi}_e(\tau, \vec{r} - \vec{r}\,') \vec{E}(t-\tau, \vec{r}\,') \mathrm{d}\tau$$

spatial dispersion $\vec{\chi}_e\left(\tau,\vec{r}-\vec{r}\,'\right)\Rightarrow\vec{\chi}_e(\omega,\vec{k}) \quad \Rightarrow\varepsilon_r\left(\omega,\vec{k}\right)$

in plasma without external field – 2 tensors $\delta_{ij}, \quad k_i k_j / k^2$

$$\overleftrightarrow{\varepsilon}_r\left(\omega,\vec{k}\right)=\varepsilon_r^l(\omega,k)\frac{k_i k_j}{k^2}+\varepsilon_r^{tr}(\omega,k)(\delta_{ij}-\frac{k_i k_j}{k^2})$$

relative permittivity (dielectric constant) for longitudinal and transverse wave

in magnetic field – plasma is conductor along *B* and dielectrics across *B*

low frequency ($\omega = 0$) permittivity of plasma (in direction normal to *B*)

$$\frac{1}{\mu_0}\mathrm{curl}\vec{B} = \vec{j}_\mathrm{v} + \vec{j}_p + \varepsilon_0\dot{\vec{E}} \qquad \varepsilon = \varepsilon_0 + \frac{j_p}{\dot{E}}$$

$$\vec{E}\perp\vec{B} \qquad \vec{j}_p = \frac{\rho_M}{B^2}\frac{d\vec{E}}{dt} \qquad \varepsilon_r = 1+\frac{\rho_M}{\varepsilon_0 B^2}$$