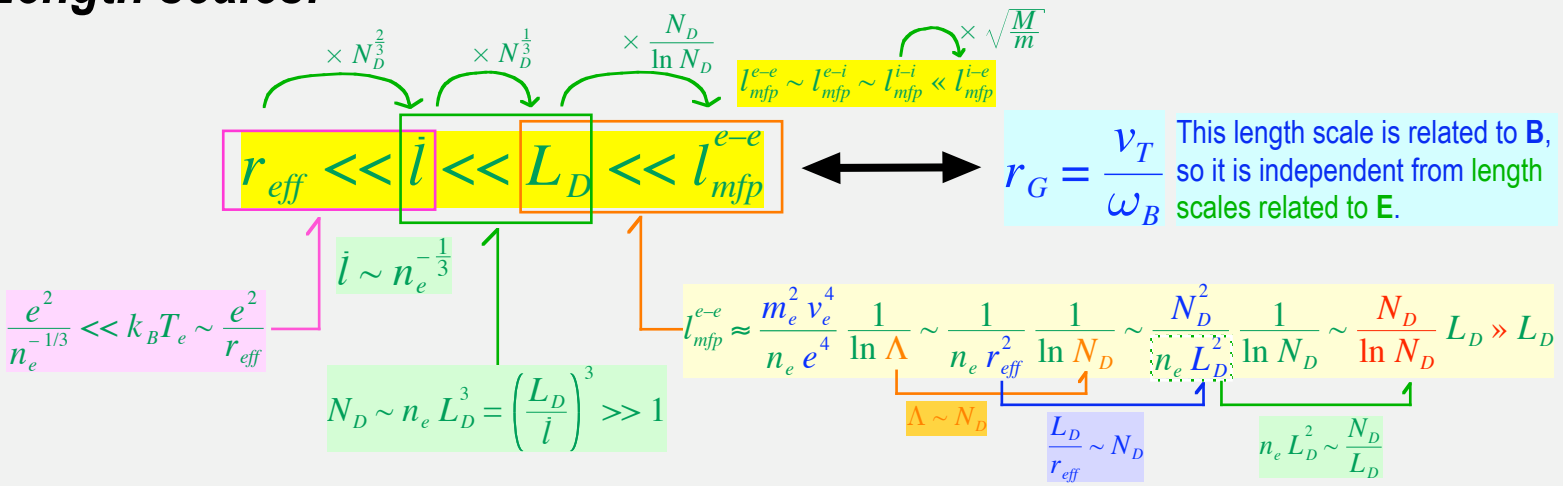
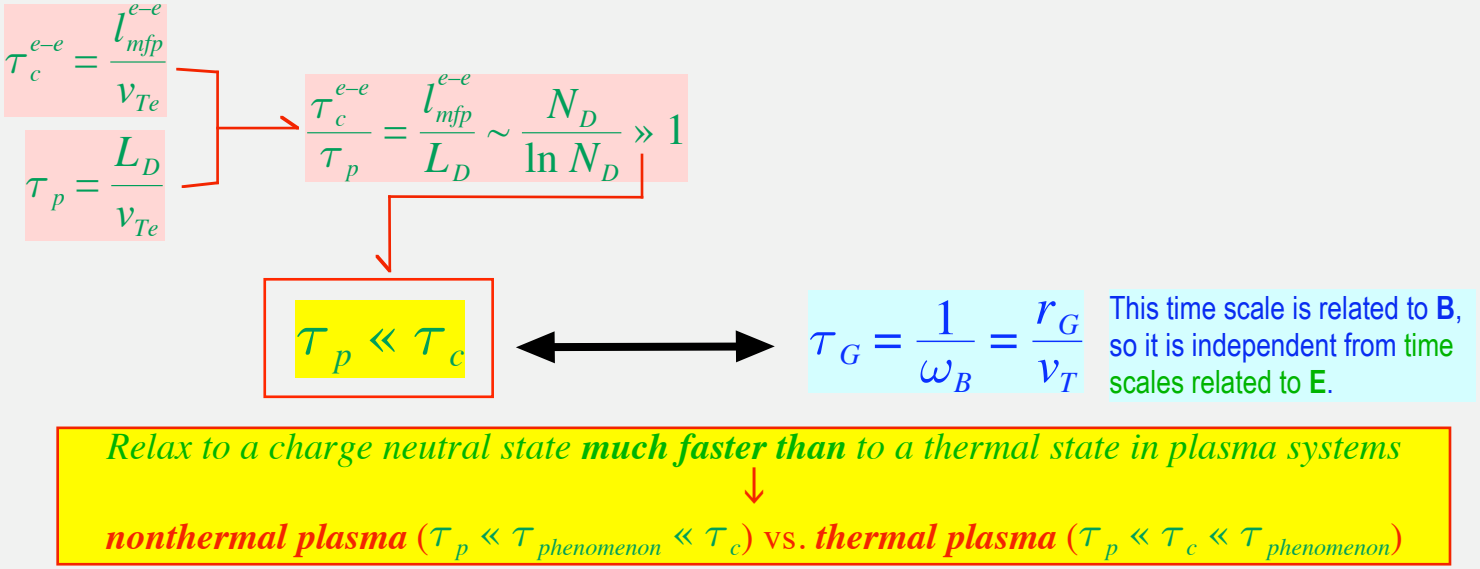
Magnitude relationship between characteristic scales

Length scales:



Time scales:



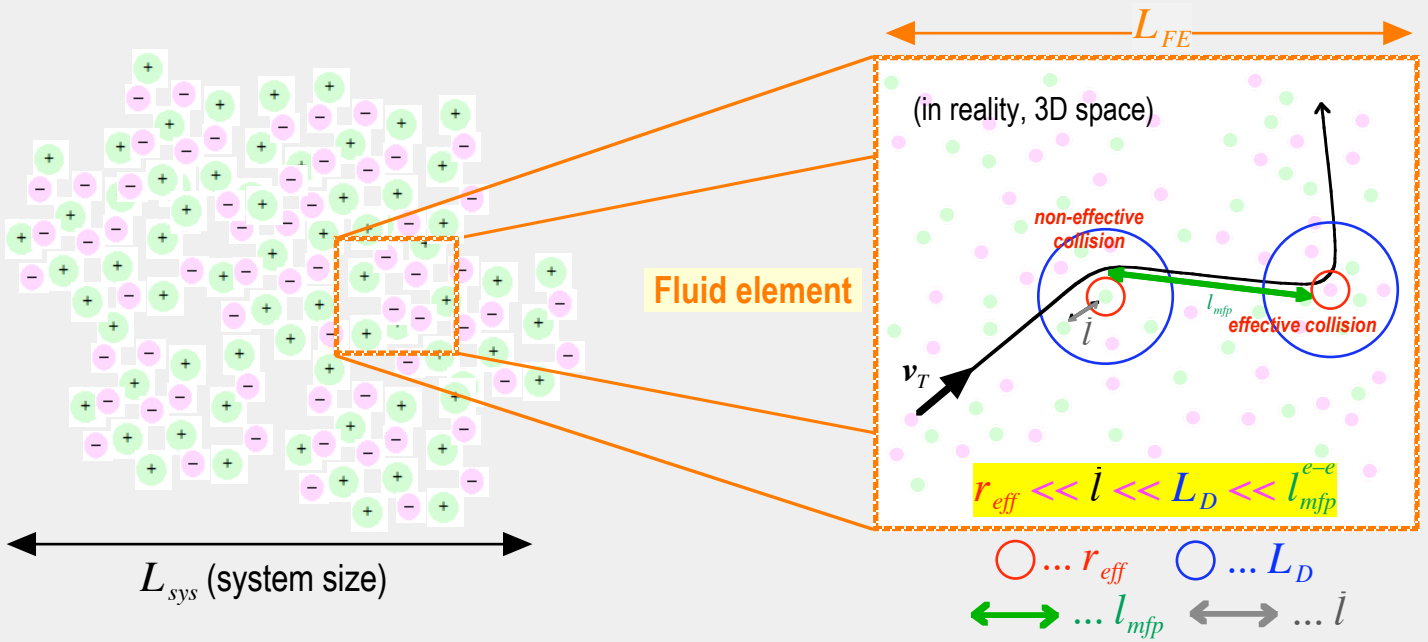
Summary of characteristic scales of plasmas

	E-related scale			**B**-related scale	
Length	mean free path (l_{mfp})	Debye length (L_D)	effective radius (r_{eff})	gyration radius (r_G)	mean interval (l)
Time	collision time $(\tau_c = \frac{l_{mfp}}{v_T})$	oscillation period $(\tau_p = \frac{L_D}{v_{Te}})$		gyration period $(\tau_G = \frac{r_G}{v_T})$	
Physical process	collision	oscillation	collision with a large scattering angle	gyration	
Physical effect	thermalization (p, T)	neutralization $(\rho_c \sim 0)$ $r_{particle} << r_{eff} << l << L_D << l_{mfp}$	thermalization (p, T)	magnetization (p, j)	
CGS unit	$l_{mfp}^{e-e} = \frac{(k_B T_e)^2}{4\pi n_e e^4} \frac{1}{\ln N_D}$	$L_D = \sqrt{\frac{k_B T}{4\pi e^2 n_e}}$	$r_{eff} \sim \frac{e^2}{k_B T}$	$r_G = \frac{m c v_T}{e B}$	$l \sim n^{-\frac{1}{3}}$

Validity of fluid approach

Validity of fluid approach

=> ***mean free path*** *and* ***gyration radius*** *are key quantities*



$l_{mfp} \ll L_{sys}$... *Fluid approach is* ***appropriate***.

It makes good physical sense to introduce a fluid element whose size L_{FE} is much smaller than L_{sys} but much larger than l_{mfp}. Particles inside the fluid element make a random walk with thermal speed v_T. They basically stay inside the element; only part of them move in or out near the boundary of the element, which is treated by **diffusion approximation**.

$l_{mfp} \gg L_{sys}$... *Fluid approach is* ***generally inappropriate***.

However, even when collision is less frequent (**collisionless plasma**), fluid approach may be valid in $B_\perp$*–plane* if $r_G \ll L_{sys}$ is satisfied and thermalization is completed (in $B_{//}$-direction we may have to take a different approach).