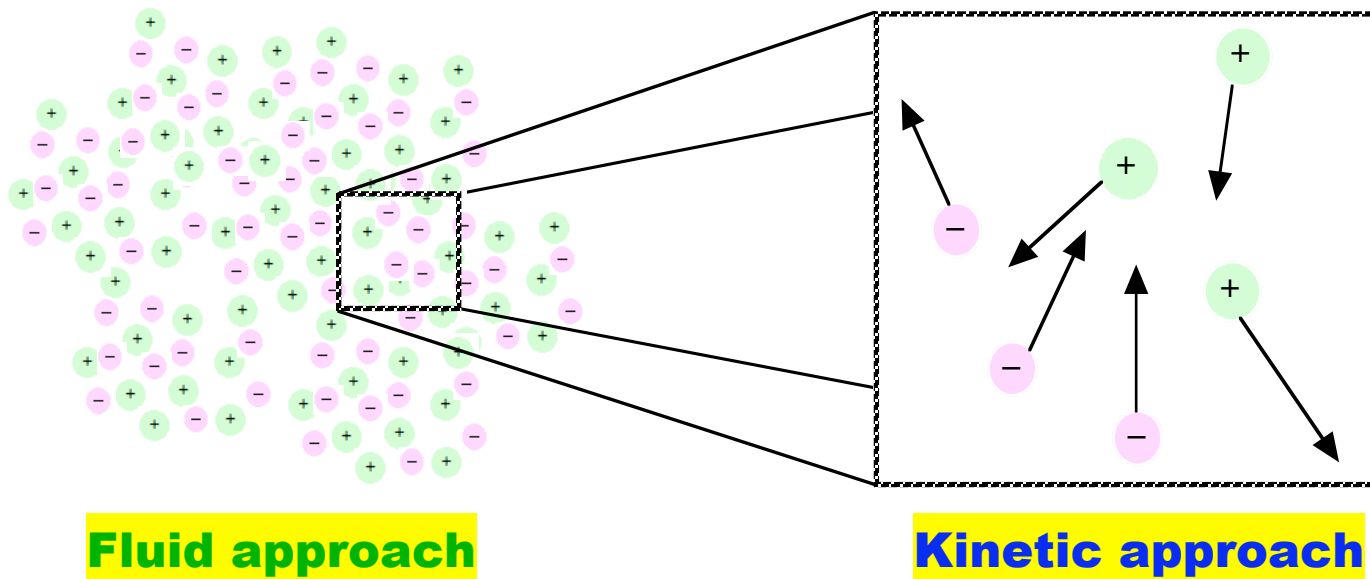


Two approaches to plasma physics

Plasma... composed of many particles

Focus on a selected *local region* → **Kinetic approach**

Focus on the *whole region* → **Fluid approach**



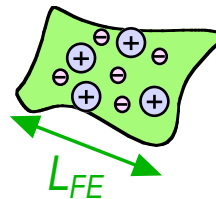
Kinetic approach

→ study *microscale* processes, the behavior of *particles*

Fluid approach

→ study *macroscale* processes, the behavior of *fluid elements**

**Fluid element...* a virtual object containing a number of particles; most of the particles keep staying inside the element ($\Rightarrow$ typical size $L_{FE} \gg l_{mfp}, r_G$)

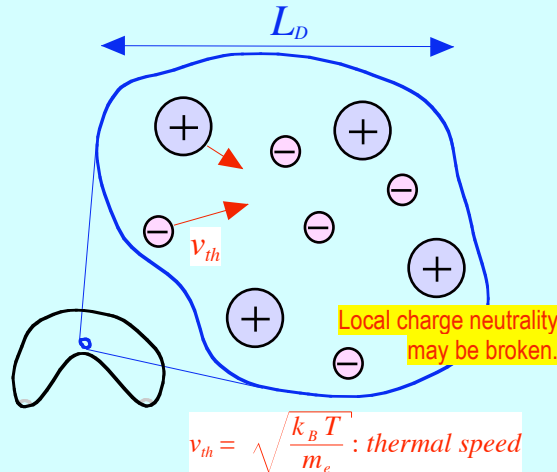


l_{mfp} : mean free path

r_G : gyration radius

Typical scales used in both approaches...

Kinetic approach... *particle* is a *fundamental object* (its internal structure is not considered)



Typical scales:

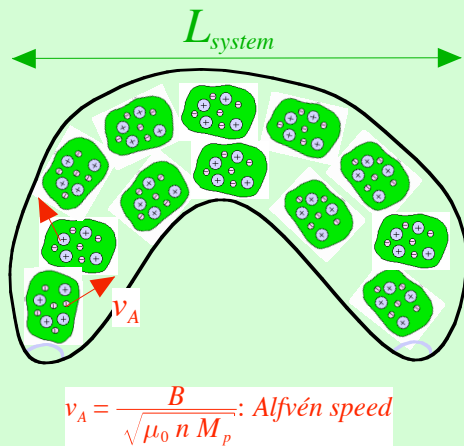
Length... L_D (Debye length)

e.g. 1 cm for a solar coronal plasma

Time... $L_D / v_{th} \sim 1 / \nu_p$ (plasma frequency)

e.g. 5×10^{-9} s for a solar coronal plasma (electron)

Fluid approach... *fluid element* is a *fundamental object* (its internal structure is not considered)



Typical scales:

Length... L_{system} (system size)

e.g. 100,000 km $\sim 10^8$ m for a coronal loop

Time... L_{system} / v_A (Alfvén speed)

e.g. 100 s for a coronal loop ($v_A \sim 1000$ km/s)

Coronal loop

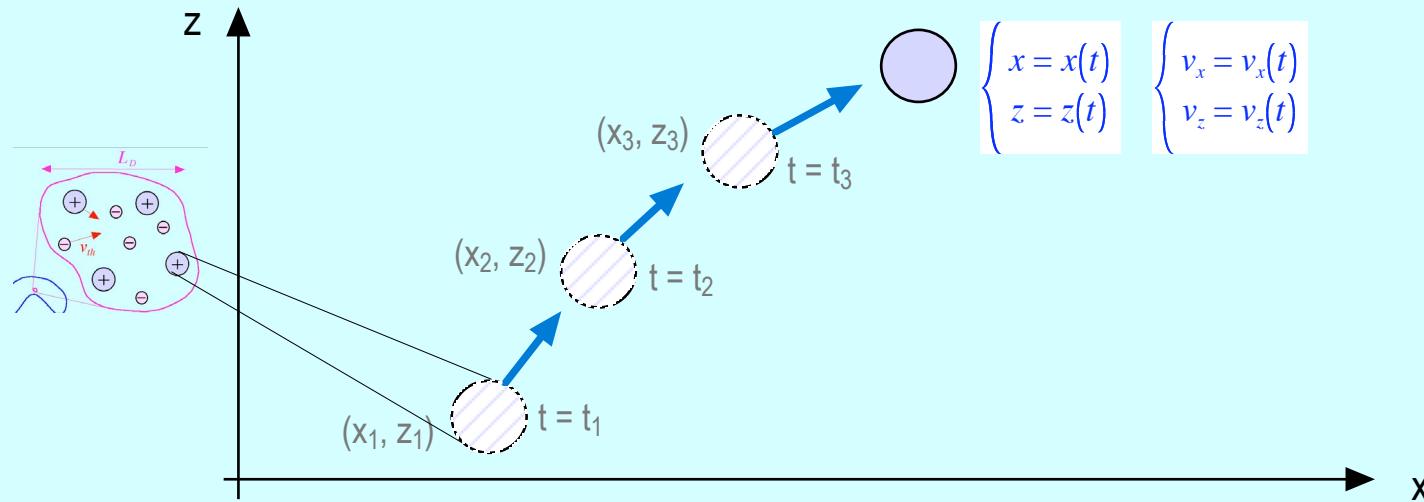


Characteristic scales of plasmas

	<i>E-related scale</i>	<i>B-related scale</i>
Length	mean free path (l_{mfp}) Debye length (L_D)	gyration radius (r_G)
Time	collision time $(\tau_c = \frac{l_{mfp}}{v_T})$ oscillation period $(\tau_p = \frac{L_D}{v_T})$	gyration period $(\tau_G = \frac{r_G}{v_T})$
Physical process	collision oscillation	gyration
Physical effect	thermalization neutralization	magnetization
CGS unit $l_{mfp}^{e-e} = \frac{(k_B T_e)^2}{4 \pi n_e e^4} \frac{1}{\ln N_D}$ $\ln N_D \sim 10$ $L_D = \sqrt{\frac{k_B T}{4 \pi e^2 n_e}}$ $r_G = \frac{m c v_T}{e B}$		

Basic equations in kinetic & fluid approaches

Kinetic approach... Focus on *position* and *velocity* of *each particle* at *every time*
=> Mechanical equation



In the **kinetic approach**, we consider the *physical state* of each *particle* represented by its *position* and *velocity*.

The *mechanical equation* is a *differential equation* where *time* is the only independent variable (**ordinary differential equation, ODE**).

$$\begin{cases} \frac{dx}{dt} = v_x(t) \\ \frac{dz}{dt} = v_z(t) \end{cases} \quad \begin{cases} m \frac{dv_x}{dt} = F_x(x(t), z(t), v_x(t), v_z(t), t) \\ m \frac{dv_z}{dt} = F_z(x(t), z(t), v_x(t), v_z(t), t) \end{cases}$$