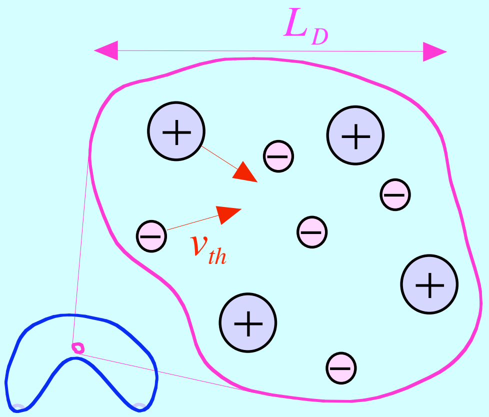
Typical scales in both approaches...

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



$v_{th} = \sqrt{\frac{k_B T}{m}}$: *thermal speed*

Typical scales:

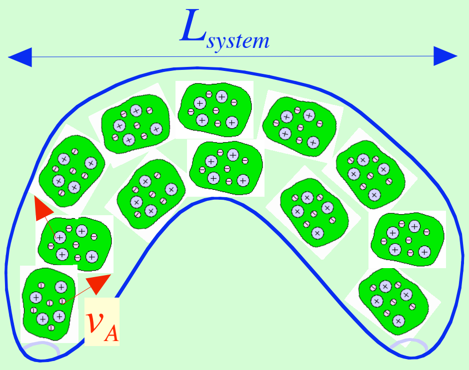
Length... L_D (Debye length)

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

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



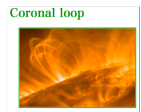
$r_{particle} << L_D << l_{mfp} << L_{FE} << L_{system}$

$r_G << L_{FE}$

Typical scales:

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

e.g., 100,000 km ~ 10^8 m for a coronal loop



Time... L_{system} / v_A ($v_A = \frac{B}{\sqrt{\mu_0 \, n \, m}}$: *Alfvén speed*)

e.g., 100 s for a coronal loop (v_A ~ 1000 km/s)

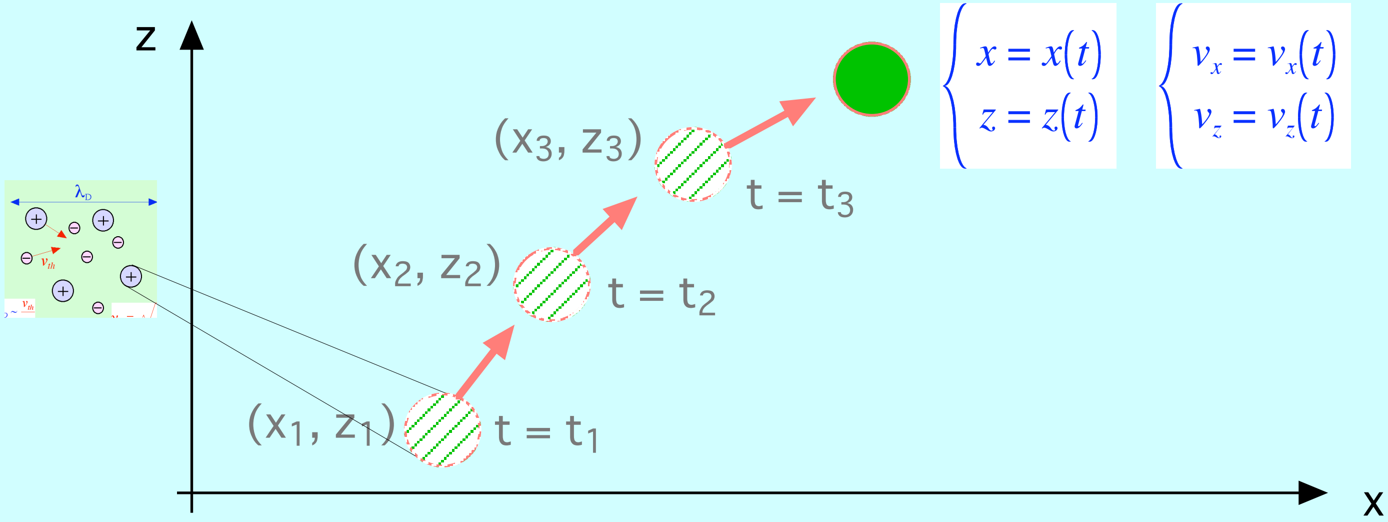
Summary of characteristic scales of plasmas

	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** ($t_c = \frac{l_{mfp}}{v_T}$)	**oscillation period** ($t_p = \frac{L_D}{v_T}$)		**gyration period** ($t_G = \frac{r_G}{v_T}$)	
Physical process	**collision**	**oscillation**	**collision** with a **large scattering angle**	**gyration**	
Physical effect	**thermalization**	**neutralization**	**thermalization**	**pressure & current** in $B_\perp$**-plane**	
CGS unit	$l_{mfp}^{e-e} = \frac{(k_B T_e)^2}{4\pi n_e e^4} \frac{1}{\ln N_D}$	$L_D = \sqrt{\frac{k_B T}{4\pi e^2 n_e}}$	$r_{eff} \sim \frac{e^2}{k_B T}$	$r_G = \frac{m c v_T}{e B}$	$l \sim n^{-\frac{1}{3}}$

Basic equations in kinetic & fluid approaches

Kinetic approach... Focus on the position and velocity of a particle at every time

=> Mechanical equation



$$\begin{cases} x = x(t) \\ z = z(t) \end{cases} \qquad \begin{cases} v_x = v_x(t) \\ v_z = v_z(t) \end{cases}$$

In the kinetic approach, we consider the **physical state** of a **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).

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