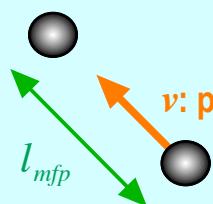


# Collision time & collision frequency

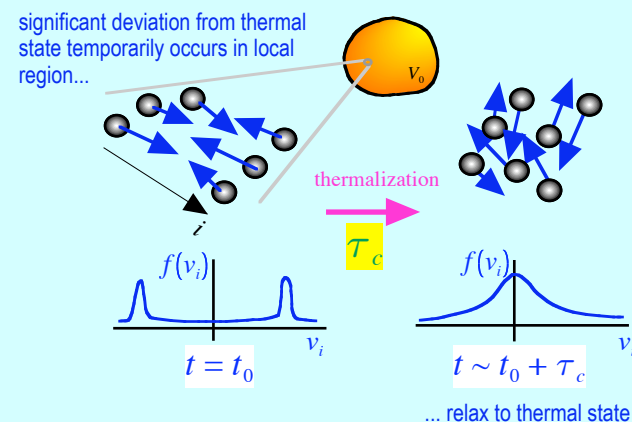
**Collision time**  $\tau_c$  ... A time required for a particle to collide with another particle  
 (Thermalization time, Thermal relaxation time) (relax to a thermal state via collision)

$$\tau_c = \frac{l_{mfp}}{v}$$



$v$ : particle's (relative) velocity  $\sim v_T \equiv \sqrt{\frac{k_B T}{m}}$   
**particle's thermal speed**

e.g.  $\tau_c^{e-e} = \frac{l_{mfp}^{e-e}}{v_{Te}} \sim \frac{m_e^2 v_e^3}{4 \pi n_e e^4 \ln \Lambda} \frac{1}{v_{Te}} = \frac{m_e^{1/2} (k_B T_e)^{3/2}}{4 \pi n_e e^4 \ln \Lambda} \frac{1}{v_{Te}} \propto m_e^{1/2}$



**Collision frequency**  $\nu_c$  ... number of collisions per unit time

$$\nu_c = \frac{\omega_c}{2\pi} = \frac{1}{2\pi} \frac{1}{\tau_c} \quad \left( \omega_c = \frac{1}{\tau_c} \right)$$

# e-i, i-i, i-e collisions

two particle model

$m$ : electron's mass,  $M$ : ion's mass

$$\tau_c^{e-e} \propto m^{1/2}$$

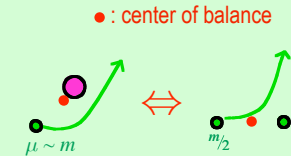
## 1) e-i collision (electron's momentum is changed by ion)

Reduced mass (relative coordinates):  $\mu = \frac{mM}{m+M} \sim m$

$$\tau_c^{e-i} \sim \tau_c^{e-e}$$

electrons become thermalized ( $T_e$  is determined)

Relative frame model

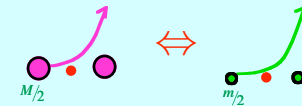


## 2) i-i collision (ion's momentum is changed by ion)

$$\tau_c^{i-i} \sim \frac{M^{1/2} (k_B T_i)^{3/2}}{n_i e^4} \sim \sqrt{\frac{M}{m}} \tau_c^{e-e} \gg \tau_c^{e-e}$$

ions become thermalized ( $T_i$  is determined)

Relative frame model



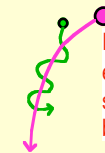
## 3) i-e collision (ion's momentum is changed by electron => momentum exchange is considered)

Ion and electron exchange the same amount of momentum per unit time:

$$M \frac{\Delta v_{90}^{relative}}{\tau_c^{i-e}} \sim m \frac{\Delta v_{90}^{relative}}{\tau_c^{e-i}}$$

$$\tau_c^{i-e} \sim \frac{M}{m} \tau_c^{e-i} \gg \tau_c^{i-i} \gg \tau_c^{e-e}$$

ions and electrons become thermalized ( $T_e \sim T_i \sim T$ : same temperature)



Ion needs a longer time ( $\tau_c^{i-e}$ ) than electron ( $\tau_c^{e-i}$ ) to achieve a large scattering angle via collision between ion and electron.

i - e collision

$\Delta v_{90}^{relative}$

during  $\tau_c^{i-e}$

e - i collision

$\Delta v_{90}^{relative}$

during  $\tau_c^{e-i}$