# Collisions in plasmas

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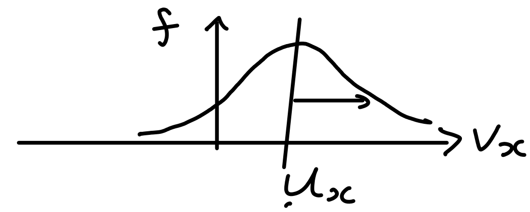
- Validity of fluid models

## Assumptions

① Local Thermodynamic Equilibrium

Maxwell-Boltzmann distribution

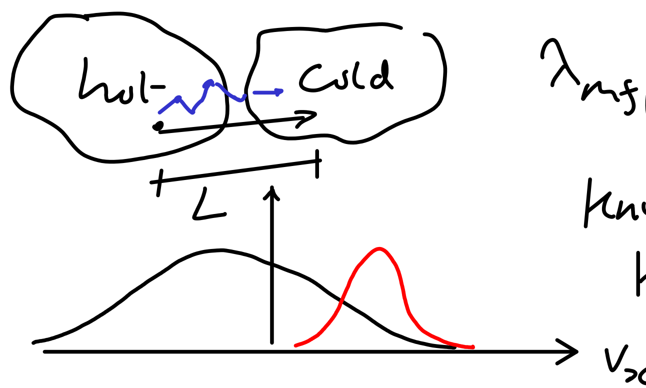



② Frequent collisions

$$\omega \ll \nu$$

wave — collision frequency

③ Short mean free path

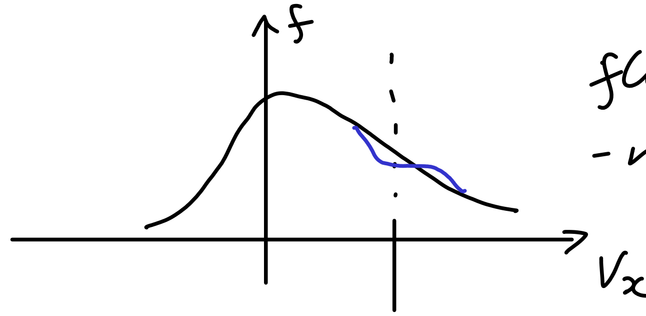



$$\lambda_{mfp} \ll L$$

Knudsen

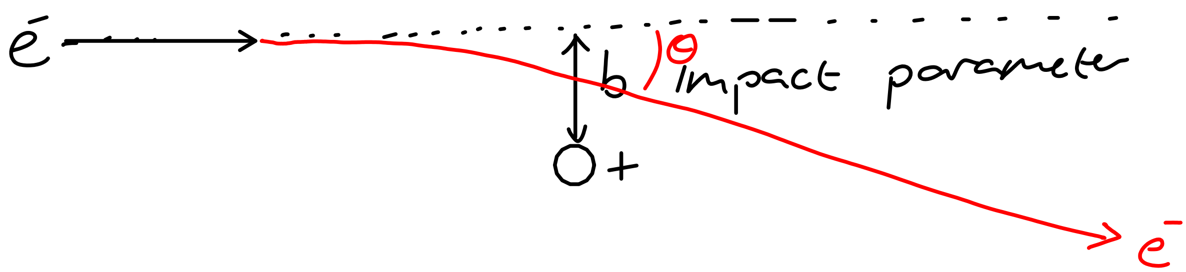
$$Kn = \frac{\lambda_{mfp}}{L} \ll 1$$

②




fluid models
- no special particles

## Collisions in plasmas




collision time

$\tau = \frac{1}{\nu}$ = average time for particle to be deflected by 90°

$\tau$ increases as plasma temperature increases
⇒ fluid models more valid for cold plasmas than hot

$$\frac{1}{\tau_e} = \frac{1}{\tau_{ee}} + \frac{1}{\tau_{ei}}$$

electron collision time; electron - electron; electron - ion

$$\tau_{ei} = 3.44 \times 10^{11} \left(\frac{1\,m^{-3}}{n_e}\right)\left(\frac{T_e}{1\,eV}\right)^{3/2} \frac{1}{Z_i \ln\Lambda}$$

$Z_i$ ← ion charge; $\ln\Lambda$ ← coulomb logarithm 10–20

## Typical Values

Core: $T \sim 10^4 eV$ $n \sim 10^{20} m^{-3}$ $\tau_{ei} \sim 1.7 \times 10^{-4} s$

Edge: $T \sim 100 eV$ $n \sim 10^{19} m^{-3}$ $\tau_{ei} \sim 1.7 \times 10^{-6} s$

Divertor: $T \sim 1 eV$ $n \sim 10^{21} m^{-3}$ $\tau_{ei} \sim 1.7 \times 10^{-11} s$

## Mean Free path $\lambda_{mfp}$

$$\lambda_{mfp} = \tau v_{th}$$

$\tau$ ↗ collision time; $v_{th}$ ↖ thermal speed

$$v_{th} = \sqrt{\frac{3eT}{m_e}}$$

Core $v_{th} \sim 7.3 \times 10^7 m/s$ $\lambda_{mfp} \sim 12 km$

Edge $v_{th} \sim 7.3 \times 10^6 m/s$ $\lambda_{mfp} \sim 12 m$

Divertor $v_{th} \sim 7.3 \times 10^5 m/s$ $\lambda_{mfp} \sim 1.2 \times 10^{-5} m$

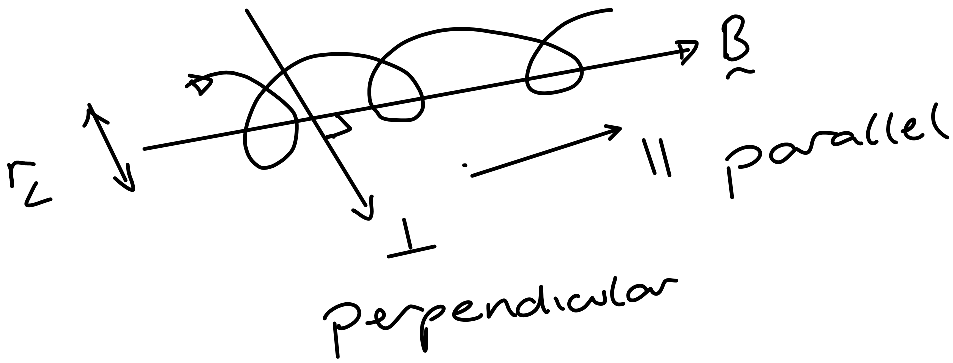
## Ion Collisions

$$\tau_{ie} = \frac{m_i}{m_e} \tau_{ei}$$

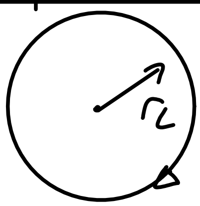
$$\tau_{ii} = \sqrt{\frac{m_i}{m_e}} \tau_{ei} \qquad v_{th,i} = \sqrt{\frac{m_e}{m_i}} v_{th,e}$$

$\Rightarrow \lambda_{mfp} = \tau v_{th}$ same for electrons and ions

# Why do fluid models work?




## Perpendicular




particles confined to orbits
$\Rightarrow$ effective mfp is $\sim r_L$

## parallel

Slow phenomena (equilibrium)
pressure, temperature etc. ~ constant

Fast phenomena (waves, resonances)
Dynamics along field can be important