e

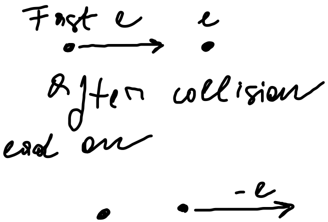
i

ν_{Eee} ν_{Eii}

ν_{Eei} ν_{Eie}

$e-e$

$i-i$

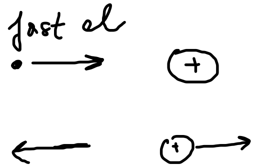


$\nu_{Eee} \sim \nu_{ee}$

$\nu_{Eii} \sim \nu_{ii}$

ν_{Eei}

Head on



$m_i >> m_e$

$\Delta \underline{v}_e = -2\underline{v}_e$

$m_i \Delta \underline{v}_i + m_e \Delta \underline{v}_e = 0$

$m_i \Delta \underline{v}_i = 2 m_e \underline{v}_e$

$\underline{v}_i = \frac{2m_e}{m_i} \underline{v}_e$

$$\frac{1}{2} m_i v_i^2 = \frac{1}{2} m_i \frac{4 m_e^2 v_e^2}{m_i^2} = 4 \frac{m_e}{m_i} \left(\frac{1}{2} m_e v_e^2 \right) = 4 \frac{m_e}{m_i} E_e$$

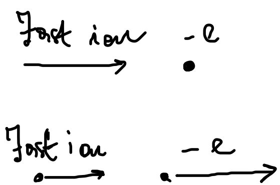
e-e ⇒ in 1 collision we can transfer most of the energy

e-i ⇒ 〃 〃 〃 〃 〃 〃 "only" $\approx \frac{m_e}{m_i} E_e$

We need $\frac{m_i}{m_e}$ more collisions to transfer all of the energy

$$\Delta E_{ei} = \frac{m_e}{m_i} \Delta E_{ee}$$

ΔE_{ie}



Head on

$\underline{v}_e = 2\underline{v}_i$ $\quad m_e \Delta \underline{v}_e = m_i \Delta \underline{v}_i$

$$\frac{1}{2} m_e v_e^2 = \frac{1}{2} m_e 4 v_i^2 = \frac{1}{2} m_e 4 \frac{m_i}{m_i} v_i^2$$

$$= 4 \frac{m_e}{m_i} \cdot K_i$$

$\nu_{Eie} \sim \frac{m_e}{m_i} \nu_{Eii}$

ν_{ei}

Summary

~ 1	$\sim \left(\frac{m_e}{m_i}\right)^{\frac{1}{2}}$	$\sim \left(\frac{m_e}{m_i}\right)$
ν_{ei}	ν_{ii}	ν_{ie}
ν_{ee}	ν_{Eii}	ν_{Eie}
ν_{Eee}		ν_{Eei}

1) Beam electron entering a plasma! → en. is transf. to electrons

Fast el. (el, i)

1) Fast electrons and fast ions

2) $(m_e/m_i)^{\frac{1}{2}}$ ion heating

3) $\left(\frac{m_e}{m_i}\right)$ transf. of E from e to i

Beam of ions in a plasma

1) $\Delta t \sim \left(\frac{m_i}{m_e}\right)^{1/2} \cdot \Delta t_{\text{mom. exch.}}$ transf. of mom. and en. to bulk plasma ions

2) $\Delta t \sim \left(\frac{m_i}{m_e}\right) \cdot \Delta t_{\text{mom exch.}}$ Transf. of en. and mom. to the ions,

$T_e \sim T_i$ $T_i > T_e$

Collisions with neutrals

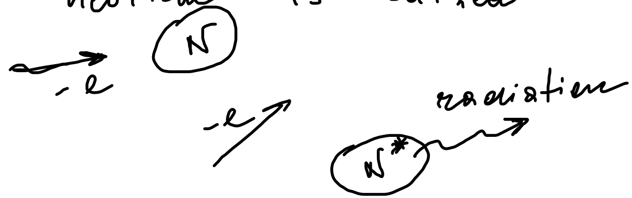
→ cold plasmas

→ edge of a fully ionized plasma

$\sigma \sim a^2$ $\sigma \sim 10^{-20}\ m^2$

1) Elastic collision

2) Inelastic = (neutral is left in an excited
neutral is ionized)



3) Charge exchange

(fast i) + neutral → fast neutral + ion

el. are faster

Edge plasma ion-neutrals

Cold plasma in eq.

$T_e \sim eV$ $T_i \sim T_{room}$