

$$\nu_{Eee} \quad \nu_{Eii}$$

$$\nu_{Eei} \quad \nu_{Eie}$$

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

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

e-e

i-i

$$\xrightarrow{\text{Fast e}} e$$

After collision

Head on

$$\bullet \quad \bullet \xrightarrow{-e}$$

$$\nu_{Eei}$$

Head on

$$\xrightarrow{\text{Fast el}} +$$

$$m_i > m_e$$

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

$$\leftarrow \quad \rightarrow$$

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

$$\frac{1}{2} m_i \underline{v}_i^2 = \frac{1}{2} m_e \underline{v}_e^2 \quad \frac{m_e \underline{v}_e^2}{m_i} = 4 \frac{m_e}{m_i} \left(\frac{1}{2} m_e \underline{v}_e^2 \right) = \\ = 4 \frac{m_e}{m_i} E_e$$

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

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

$e - e \Rightarrow$ in 1 collision we can transfer most of the energy

$e - i \Rightarrow = = = = = = = =$ "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_{ei} 

ΔE_{ei} 

Head on

$$\Delta E_e = 2 \Delta E_i$$

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

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

Summary ν_{ei}

$$\sim 1 \quad \sim \left(\frac{m_e}{m_i} \right)^{\frac{1}{2}} \quad \sim \left(\frac{m_e}{m_i} \right)$$

$$\nu_{ei}$$

$$\nu_{ii}$$

$$\nu_{ie}$$

$$\nu_{ee}$$

$$\nu_{Eii}$$

$$\nu_{Eie}$$

$$\nu_{Eee}$$

$$\nu_{Eci}$$

1) Beam electron entering plasma! \rightarrow en. is transf. to electrons

Fast el. $\begin{matrix} \text{el}^- \\ \text{i}^- \end{matrix}$

1) Fast electrons and fast ions

2) $(\frac{m_e}{m_i})^{\frac{1}{2}}$ ion heating 3) $(\frac{m_e}{m_i})$
 E beam e to i

Beam of ions in a plasma

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

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

$$T_e \sim T_i$$

$$\underline{\underline{T_i > T_e}}$$

Collisions with neutrals

→ cold plasmas

→ edge of a fully ionized plasma

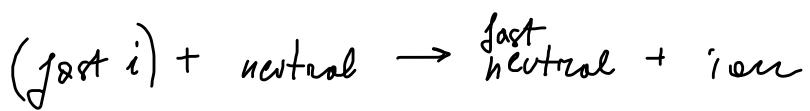
$$\sigma \sim a^2 \quad \sigma \sim 10^{-20} m^2$$

1) Elastic collision

2) Inelastic \Rightarrow (neutral is left in an excited state
neutral is ionized)

The diagram shows a horizontal arrow pointing towards a circle labeled 'N'. Below the arrow is '-e-' indicating an incoming electron. After the collision, the circle 'N' is split into two circles: one labeled 'N+' and one labeled 'e-'. A curved arrow from the original 'N' to the 'N+' circle is labeled 'radiation'.

3) Charge exchange



Edge
cold

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

el. are fast

ion-neutrals

in eq.

