

$E \times B$ drift velocity

$$\vec{v} = -c \left\{ B_z + \frac{mc}{q} \left(\frac{cE_A \sin\{2\pi(\frac{t}{T} - \frac{m_{num}\theta}{2\pi}) + \frac{\pi}{2}\}}{B_z^2} \xi_r \right) \right\}^{-1} \left(E_A \sin\{2\pi(\frac{t}{T} - \frac{m_{num}\theta}{2\pi}) + \frac{\pi}{2}\} - \frac{\mu}{q} \xi_r + \frac{mc^2}{q} \frac{(E_A \sin\{2\pi(\frac{t}{T} - \frac{m_{num}\theta}{2\pi}) + \frac{\pi}{2}\})^2 \xi_r}{B_z^3} \right) \vec{e}_\theta$$

if electric field is constant,

$$\vec{v} = -c \left\{ B_z + \frac{mc}{q} \left(\frac{cE_A}{B_z^2} \xi_r \right) \right\}^{-1} \left(E_A - \frac{\mu}{q} \xi_r + \frac{mc^2}{q} \frac{(E_A)^2 \xi_r}{B_z^3} \right) \vec{e}_\theta$$

assumption: $E_A = 3 \text{ mV/m}$

$$3 \text{ mV} = 3 \times 10^{-3} \times \frac{10^8}{3.0 \times 10^{10}} \text{ statV} = 10^{-5} \text{ statV}$$

$$3 \text{ mV/m} = 10^{-7} \text{ statV/cm}$$

assumption $B_z = \frac{B_E}{L^3}$ (in magnetic equator), $B_E = 3.11 \times 10^{-5} \text{ T} = 3.11 \times 10^{-1} \text{ G}$

if $L = 6$, $B_z = 1.4 \times 10^{-7} \text{ T} = 1.4 \times 10^{-3} \text{ G}$

assumption : $v_\perp = 0.01c = 3.0 \times 10^8 \text{ cm/s}$

$$\mu = \frac{mv_\perp^2}{2B_z} = \frac{(9.1 \times 10^{-28} \text{ g}) \times (3.0 \times 10^8 \text{ cm/s})^2}{2.0 \times 1.4 \times 10^{-3} \text{ G}}$$

$$\xi_r = \frac{\partial B_z}{\partial r} = \frac{\partial B_z}{\partial L} \frac{\partial L}{\partial r} = -3 \frac{B_E}{L^4} \frac{1}{R_0} = \frac{-3 \times 3.1 \times 10^{-1} \text{ G}}{6^4 \times 6 \times 10^8 \text{ cm}}$$

$$\begin{aligned} \left\{ B_z + \frac{mc}{q} \left(\frac{cE_A}{B_z^2} \xi_r \right) \right\} &= 1.4 \times 10^{-3} \text{ G} + \\ \frac{9.1 \times 10^{-28} \text{ g} \times 3.0 \times 10^{10} \text{ cm/s}}{4.8 \times 10^{-10} \text{ statC}} \left(\frac{3.0 \times 10^{10} \text{ cm/s} \times 10^{-7} \text{ statV/cm}}{(1.4 \times 10^{-3} \text{ G})^2} - \frac{3 \times 3.1 \times 10^{-1} \text{ G}}{6^4 \times 6 \times 10^8 \text{ cm}} \right) &= 1.4 \times 10^{-3} \text{ G} - \\ \frac{9.1 \times 3.0 \times 3.0 \times 3 \times 3.1}{4.8 \times 1.4 \times 1.4 \times 6^4 \times 6} \frac{10^{-16}}{10^{-8}} &= 1.4 \times 10^{-3} \text{ G} - 0.01 \times 10^{-8} \text{ G} \end{aligned}$$

about $(E_A - \frac{\mu}{q} \xi_r + \frac{mc^2}{q} \frac{(E_A)^2 \xi_r}{B_z^3}) \vec{e}_\theta$

$$E_A = 10^{-7} \text{ statV/cm}$$

$$\begin{aligned} \frac{\mu}{q} \xi_r &= \frac{(9.1 \times 10^{-28} \text{ g}) \times (3.0 \times 10^8 \text{ cm/s})^2}{2.0 \times 1.4 \times 10^{-3} \text{ G}} \times \frac{1}{4.8 \times 10^{-10} \text{ statC}} \times \frac{-3 \times 3.1 \times 10^{-1} \text{ G}}{6^4 \times 6 \times 10^8 \text{ cm}} = -\frac{9.1 \times 3.0 \times 3.0 \times 3 \times 3.1}{2.0 \times 1.4 \times 4.8 \times 6^4 \times 6} \times \\ \frac{10^{-13}}{10^{-5}} \text{ statV/cm} &= -0.0073 \times 10^{-8} \text{ statV/cm} = -7.3 \times 10^{-11} \text{ statV/cm} \end{aligned}$$

$$\begin{aligned} \frac{mc^2}{q} \frac{(E_A)^2 \xi_r}{B_z^3} &= \frac{mc}{q} \left(\frac{c(E_A)^2 \xi_r}{B_z^3} \right) = \left\{ \frac{mc}{q} \left(\frac{cE_A \xi_r}{B_z^2} \right) \right\} \left(\frac{E_A}{B_z} \right) = -(0.01 \times 10^{-8} \text{ G}) \times \frac{10^{-7} \text{ statV/cm}}{1.4 \times 10^{-3} \text{ G}} = \\ -\frac{1}{1.4} \times 10^{-14} \text{ statV/cm} &= -7.1 \times 10^{-15} \text{ statV/cm} \end{aligned}$$

$$\begin{aligned} v &= -c \left\{ B_z + \frac{mc}{q} \left(\frac{cE_A}{B_z^2} \xi_r \right) \right\}^{-1} \left(E_A - \frac{\mu}{q} \xi_r + \frac{mc^2}{q} \frac{(E_A)^2 \xi_r}{B_z^3} \right) = \\ c \frac{(10^{-7} \text{ statV/cm} - 7.3 \times 10^{-11} \text{ statV/cm} - 7.1 \times 10^{-15} \text{ statV/cm})}{1.4 \times 10^{-3} \text{ G} - 0.01 \times 10^{-6} \text{ G}} &= 3.0 \times 10^{10} \text{ cm/s} \times (7.1 \times 10^{-5} - 5.2 \times \\ 10^{-8} - 5.0 \times 10^{-12}) &= (2.1 \times 10^6 - 1.6 \times 10^3 - 1.5 \times 10^{-1}) \text{ cm/s} \end{aligned}$$

from Basic space plasma physics

$$|\vec{v}_E| = v_E = \frac{E}{B} = \frac{3\text{mV/m}}{1.4 \times 10^{-7} T} = 2.1 \times 10^4 \text{m/s}$$