Lecture 12

Polarization Drift

\[ v_p = \frac{m \ddot{E}}{qB^2} \]

in direction of \( \vec{E} \)
depends on charge and mass (indirectly)

\[ v_p = \frac{1}{\omega_0B} \frac{\ddot{E}}{dt} \]

if \( E = E_0 \cos \omega t \)

Then \( |v_p| = \frac{\omega}{\omega_0} \frac{E_0}{B} \)

\( \omega \) gets small if frequency is much lower

than gyro frequency

Example:

Imagine particles at rest in a \( B \) field and suddenly turning on \( E \) field

\[ |E| \]

\( E_0 \)

\( E_0 \)

\( c = 0 \)
during 1st 1/4 gyro period there is a net shift of θ to right by \( \Phi_1 \) and \( \Phi_2 \) charge to left by \( \Phi_2 \).

This is a transient current which disappears after \( E \) becomes steady and after one ion gyro period. After that the particles just \( E \times B \) drift.

What about \( \frac{dB}{dt} \); time varying \( B \) field?

Cannot energize a particle with a \( B \) field, but \( \dot{B} = \nabla \times \dot{E} \)

Since \( \dot{m} = \text{const} \) for slowly varying \( B \) field

as \( B \) changes, \( \frac{1}{2} m v_f^2 \) must increase

\( \Rightarrow \) Adiabatic Compression or heating occurs
Flux through gyros a bit is conserved

\[ M = \frac{mv_\perp^2}{2B} = \text{const.} \]

\[ \rho = \frac{mv_\perp}{qB} \]

\[ v_\perp = \sqrt{\frac{m^2 B}{m}} \]

\[ v_\perp \uparrow \text{ by square root of } B \uparrow \text{ as } B \]

So \( \rho \) gets smaller.

Early plasma heating devices used this technique.

Similar effects occur in magnetosphere when magnetosphere is suddenly compressed by enhanced solar wind.
Applications of Adiabatic Particle Motion to Magnetospheric Problems

1. South Atlantic Anomaly

\( B \) is weaker, so mirror points are lower. Hence more precipitation. (see figures)

2. Energy distribution shaped by radial diffusion

\[
M = \text{const} = \frac{\frac{1}{2}mv^2}{B}
\]

Assume \( V_{z1} = 0 \)

If particle drifts from \( L = 10 \) to \( L = 1 \)

Then

\[
\frac{M}{B(10\text{Re})} = \frac{\text{Energy}(1)}{B(\text{Re})}
\]

\[
B \propto \frac{1}{r^3} \quad \text{so} \quad \text{Energy}(r = \text{Re}) = \frac{B(\text{Re})}{B(10\text{Re})} \quad \text{Standing}
\]

Assume source of \( r = 10\text{Re} \)
\[
\frac{B(1)}{B(10)} = \left(\frac{1}{10R_E}\right)^3 = 1000
\]

So energy gain is 1000 times!

inner radiation belts have highest energy

Show figure

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Corotation Electric Field

rotating magnetized, conducting earth

Plasmasphere corotates.

The ionosphere polarizes because of Lorentz Force

+ see north and - toward equator

Giving Corotation Field (\(\sim 10 \text{ to } 15 \text{ mV/m}\))

\(\nabla \times B\) is a good conductor along field lines

so \(\Delta V\) ionosphere = \(\Delta V\) magnetosphere
$E_{dd}$ = dawn to dusk electric field across magnetosphere (due to MHD generator - see next section of course)

Hot plasma

causes $E' = -E_{dd}$

Alfvén Shield, inner layer