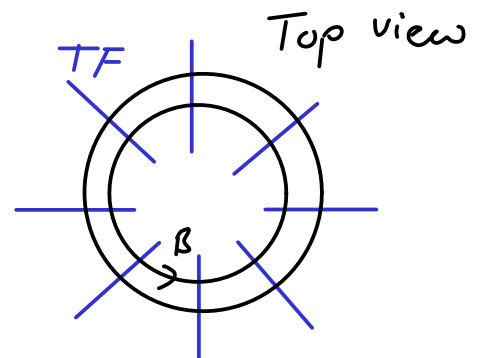
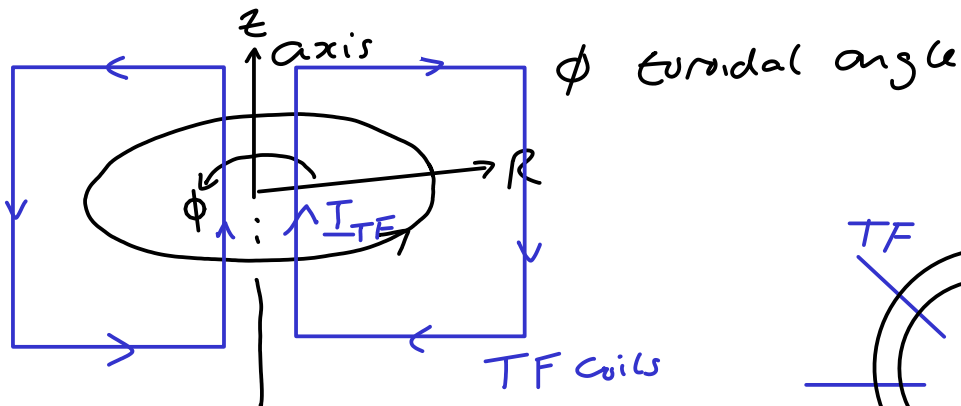
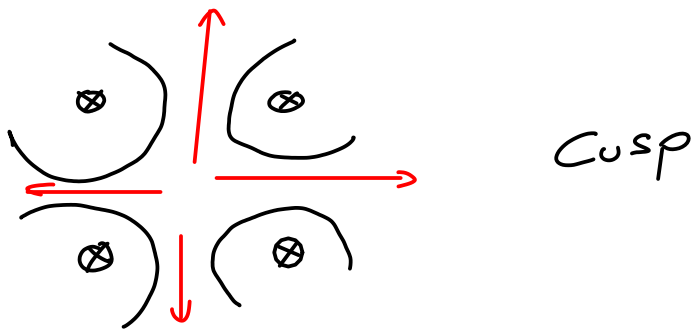
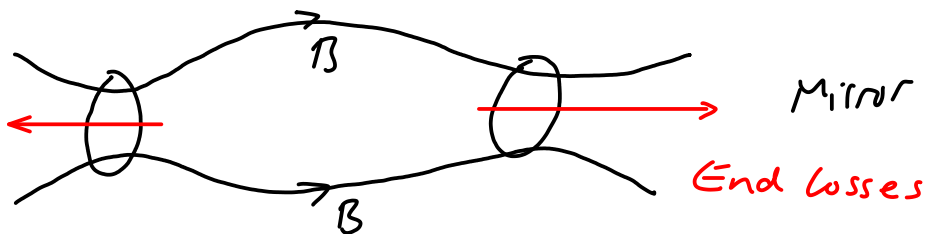
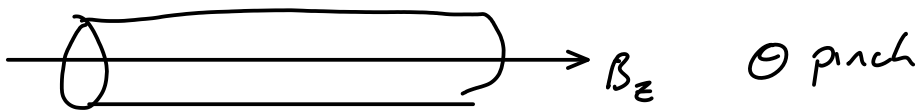


Toroidal devices

Contents

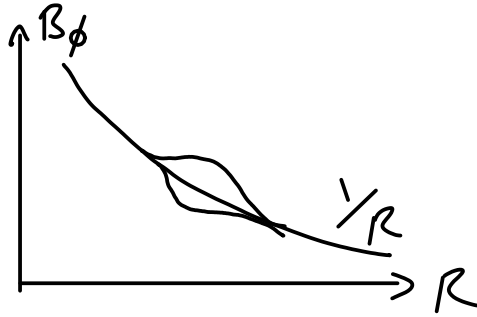
- Why toroidal?
- Particle orbits in toroidal magnetic field
- MHD force balance



$$\oint \underline{B} \cdot d\underline{l} = \mu_0 I \leftarrow N I_{TF}$$

$$B_\phi 2\pi R = \mu_0 I$$

$$B_\phi = \frac{\mu_0 I}{2\pi R}$$

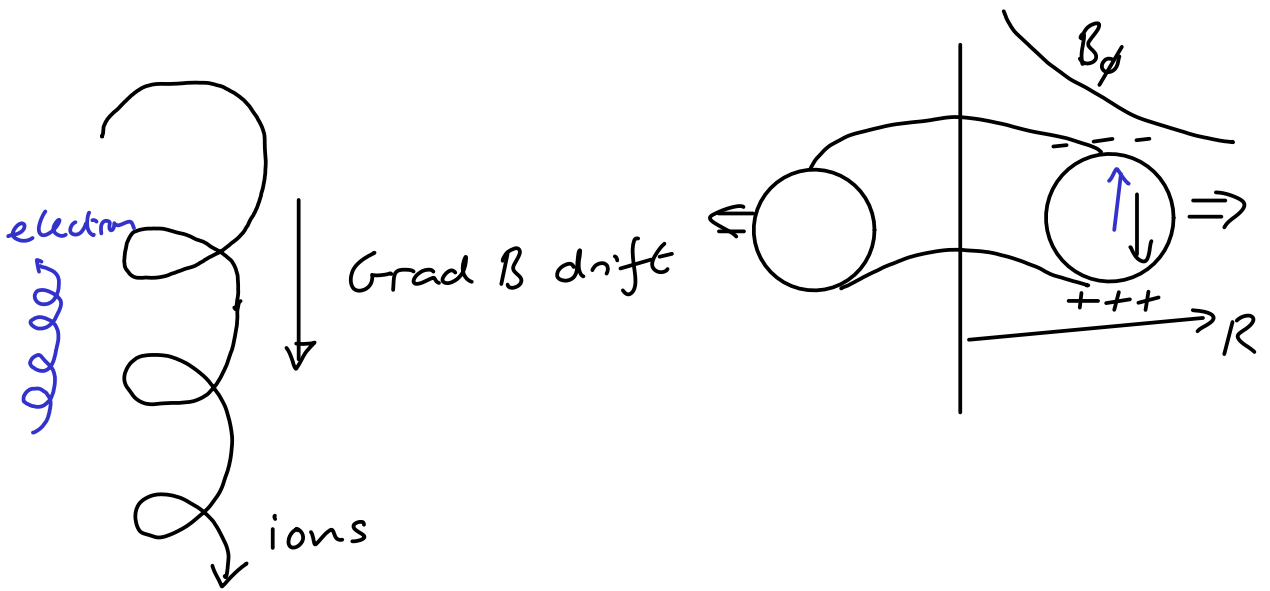


$$B_\phi \sim \frac{1}{R}$$

Particle dynamics

A diagram showing a particle with charge q moving in a circular path of radius r_L in a magnetic field B directed out of the page (indicated by a circle with a cross). The gyroradius is labeled r_L and the cyclotron frequency is labeled $\Omega = \frac{qB}{m}$. Below the diagram, the relationship $r_L = \frac{v_\perp}{\Omega}$ is written, leading to $r_L \propto \frac{1}{B}$.

high B $\leftarrow \nabla B$ low B



MHD description

Force balance $\underline{j} \times \underline{B} = \nabla P$

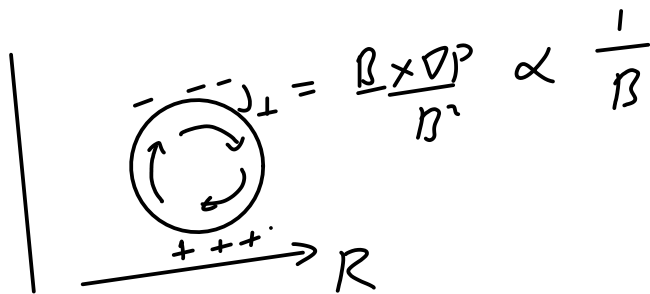
$$\underline{j}_{\perp} = \frac{\underline{B} \times \nabla P}{B^2}$$

$$\underline{j} = \underline{j}_{\perp} + j_{\parallel} \frac{\underline{B}}{B}$$

$$\nabla \cdot \underline{j}_{\perp} = \nabla \cdot \left(\frac{\underline{B} \times \nabla P}{B^2} \right) = - \nabla \cdot \left(P \nabla \times \frac{\underline{B}}{B^2} \right) = - \nabla \times \frac{\underline{B}}{B^2} \cdot \nabla P$$

$$\nabla \times \left(P \frac{\underline{B}}{B^2} \right) = \nabla P \times \frac{\underline{B}}{B^2} + P \nabla \times \left(\frac{\underline{B}}{B^2} \right)$$

If B non-uniform, then $\nabla \cdot \underline{j}_{\perp} \neq 0$



$\nabla \cdot \underline{j} = 0$ to avoid charge separation

$$\underline{j} = \underline{j}_{\perp} + j_{\parallel} \frac{\underline{B}}{B}$$

$$\uparrow$$

$$\nabla \cdot \underline{j}_{\perp} \neq 0$$

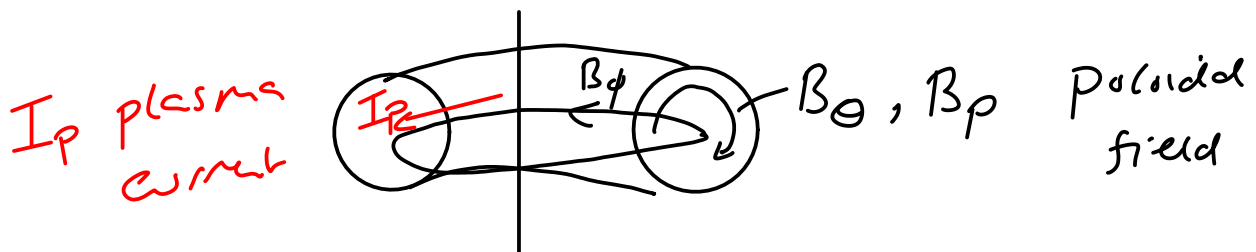
if purely toroidal

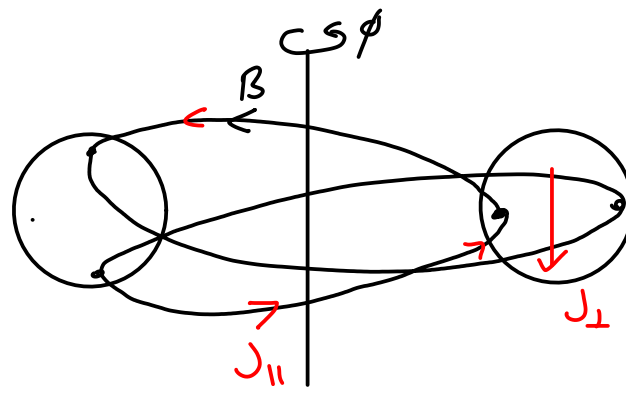
$$\underline{B} = B_{\phi} \hat{\phi}$$

$$\nabla \cdot (j_{\parallel} \hat{\phi}) = 0$$

$$\Rightarrow \nabla \cdot \underline{j} \neq 0$$

Need a poloidal magnetic field





$$\nabla \cdot \underline{J}_{\parallel} = -\nabla \cdot \underline{J}_{\perp}$$

$$\Rightarrow \nabla \cdot \underline{J} = 0$$