Magnetic Reynolds Number Approach

- Useful for modeling eddy currents, loads and heating in dewar walls, radiation shields, vacuum vessels, etc. where $\boldsymbol{R_m} \ll \mathbf{1}$.

- Two geometrically similar cases with the same $\boldsymbol{R_m}$ respond in the same way, even if there are differences:

  - Example, Two slabs with conductivities σ differing by a factor of 2 will behave the same if the one with lower σ has a thickness $\sqrt{\mathbf{2}}$ greater than the other.

- When $\boldsymbol{R_m} \ll \mathbf{1}$ the diffusion process is fast compared to the process of changing the driving field.

High R_m Approach

For a 2-D Structure:

$$R_m = \frac{\mu_o \sigma l_1 l_2}{\tau}$$

For a shell then $l_1 = R_o$, $l_2 = a$, $\rightarrow$ $R_m = \dfrac{\mu_o \sigma R_o a}{\tau}$

- Eddy currents maintain the field distribution in the region being shielded in the t < 0 condition for the instant $t = 0^+$.
- The field distribution inside the shell at $t = 0^+$ will satisfy the governing equations and boundary conditions but is expected to differ from the t < 0 condition.
- For example: Consider tokamak vacuum vessel when there is a plasma disruption. The eddy current directions will image the plasma current.
- For $R_m >> 1$ diffusion is much slower than the time to change the driving field.

For Low R_m Approximation
$R_m << 1$

$$\hat{\nabla}^2 \hat{B}_n = \frac{\partial}{\partial \hat{t}} \left(\hat{B}_{n-1} \right) \tag{1}$$

$$\hat{\nabla}^2 \hat{J}_n = \frac{\partial}{\partial \hat{t}} \left(\hat{J}_{n-1} \right) \tag{2}$$

$$\hat{\nabla} \times \hat{J}_n = -\frac{\partial}{\partial \hat{t}} \left(\hat{B}_{n-1} \right) \tag{3}$$

$$\hat{\nabla} \times \hat{B}_n = \hat{J}_n \tag{4}$$

<u>Method of Solution:</u>

use $\boldsymbol{\hat{B}_o}$ to find $\boldsymbol{\hat{J}_1}$ from (3)

then use $\boldsymbol{\hat{J}_1}$ to find $\boldsymbol{\hat{B}_1}$ from (4)

then use $\boldsymbol{\hat{B}_1}$ to find $\boldsymbol{\hat{J}_2}$ from (3)

then use $\boldsymbol{\hat{J}_2}$ to find $\boldsymbol{\hat{B}_2}$ from (4)

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(*etc*)