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The Campbell model as a tool to introduce students to AC loss calculation in superconductors

Francesco Grilli, Enrico Rizzo

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- Portability $\rightarrow$ Students can run model on their laptops

Campbell's implementation of the CSM

- State variable: magnetic vector potential A

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- Current density ($\pm J_c$) given by the sign of A

$$\nabla^2 A = -\mu_0 J_c \operatorname{erf}(-A/A_r) \qquad (1)$$

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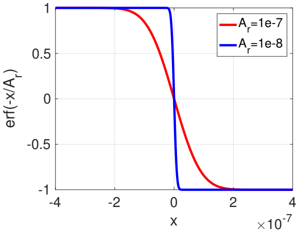

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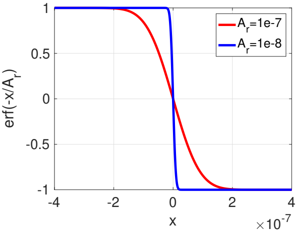
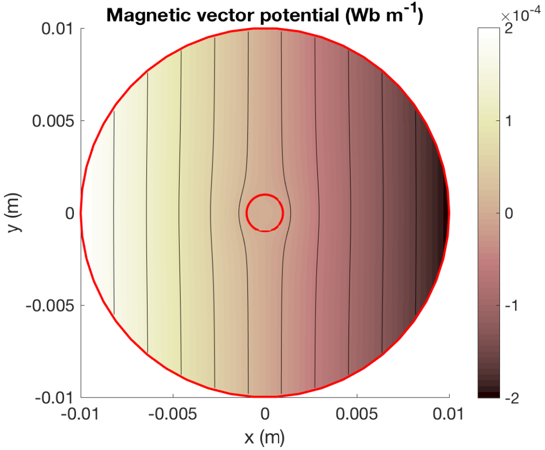


- For certain problems, cyclic AC losses can be computed from A at the peak

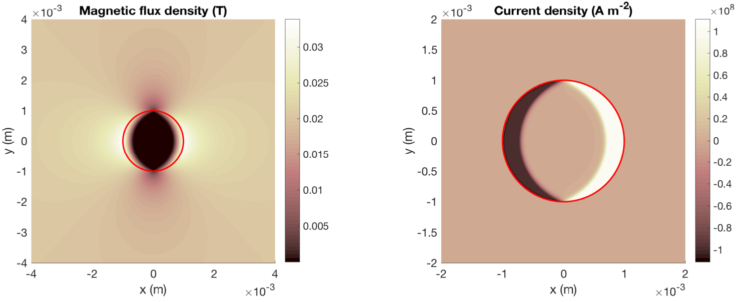
$$Q = -4 \int_\Omega J_\mathrm{p} A_\mathrm{p} \mathrm{d}\Omega \quad (2)$$

Magnetization of a round wire (in 2D)

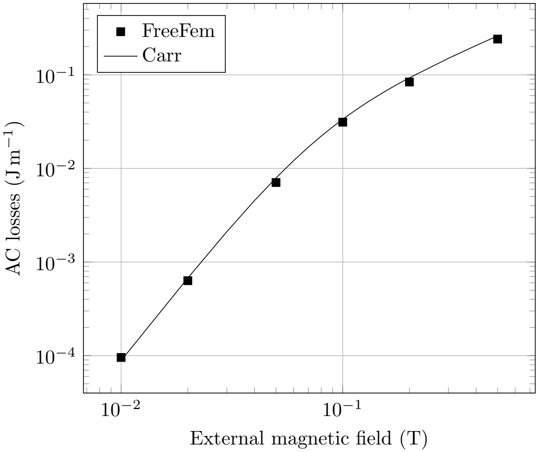


Magnetic field B_a obtained with boundary condition $A = -B_a x$ on the outer domain

Magnetic field and current density distributions



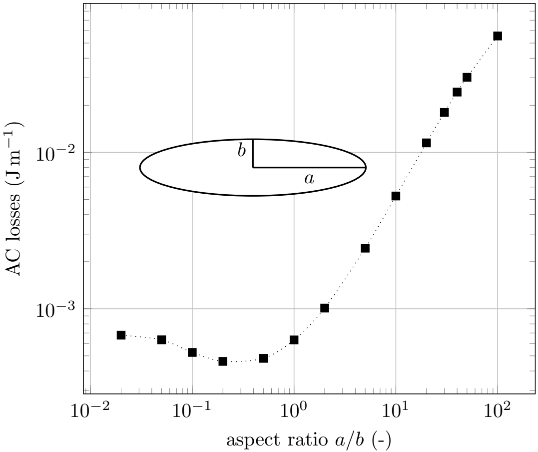
Exercise 1



Verify analytical expressions for AC losses of a round wire

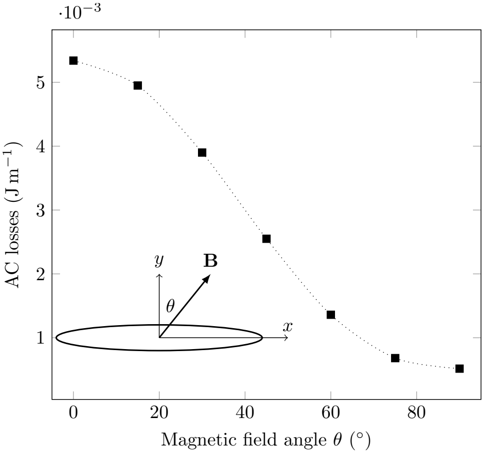
 W. J. Carr Jr., “AC Loss and Macroscopic Theory of Superconductors”, CRC Press

Exercise 2



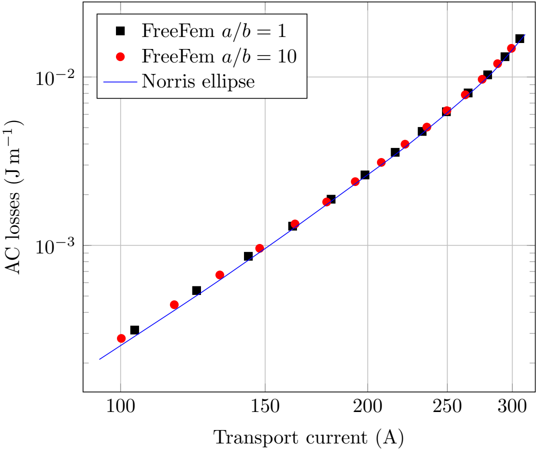
For a fixed field amplitude, modify the aspect ratio of the ellipse (same cross section)

Exercise 3



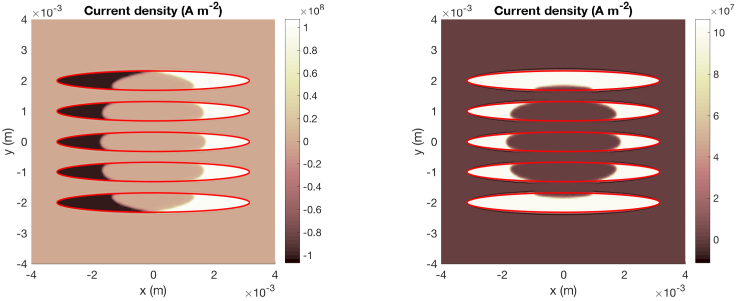
For a fixed field amplitude, change the field direction

Exercises 4: transport current



Verify Norris's formula (results independent of aspect ratio)

Further: stack of tapes



Current density distributions for the magnetization (left) and transport (right) cases.
Each tape behaves differently, influence of separation, etc.

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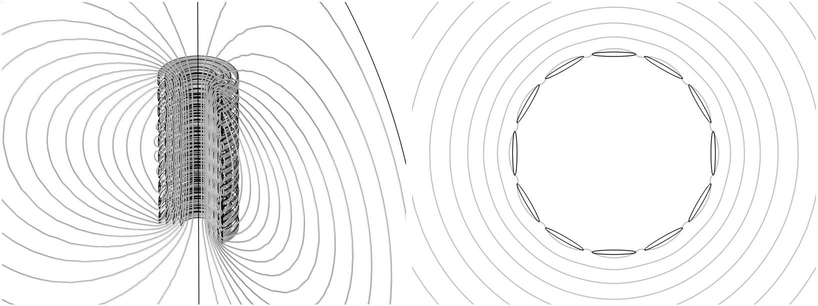
  - Simple cases (no current + field, current constraints, etc.)
- Advantages
  - Easy to implement & run
  - Each student can run different cases $\rightarrow$ engagement
  - Students can grasp some important aspects of real applications

Solenoids & power cables



More details in this publication

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