

12-Magnetic Circuits

ECEGR 3500

Electrical Energy Systems

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→ Overview

- Introduction
- Ferromagnetic Materials
- Magnetic Circuit Assumptions
- Observations of Magnetic Circuits

→ Introduction

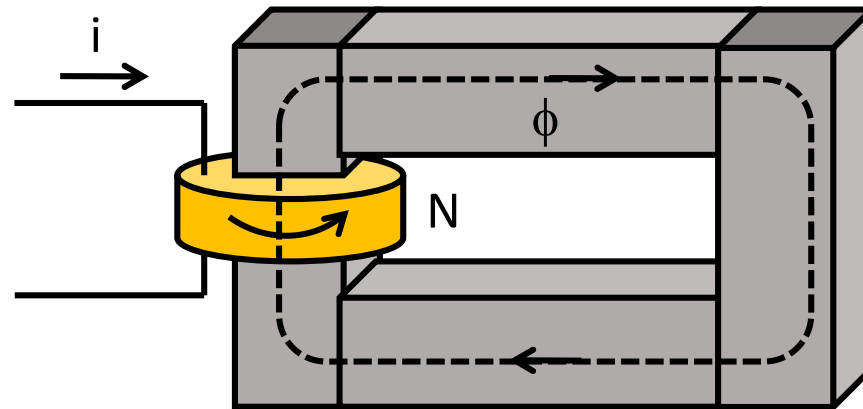
- Faraday's Law is the basis for transformer operation
- Application of Faraday's Law requires knowledge of flux density
- How can these quantities be computed for a given physical arrangement?

→ Ferromagnetic Materials

- Experience a strong attractive force to an applied magnetic field
 - Force can be several thousand times stronger than that in paramagnetic materials
 - Resulting magnetic field may be stronger than the applied field
- Ferromagnetic materials include
 - Iron, cobalt, nickel
- Relative permeability may be several thousand (compared with 1.0 for free space)

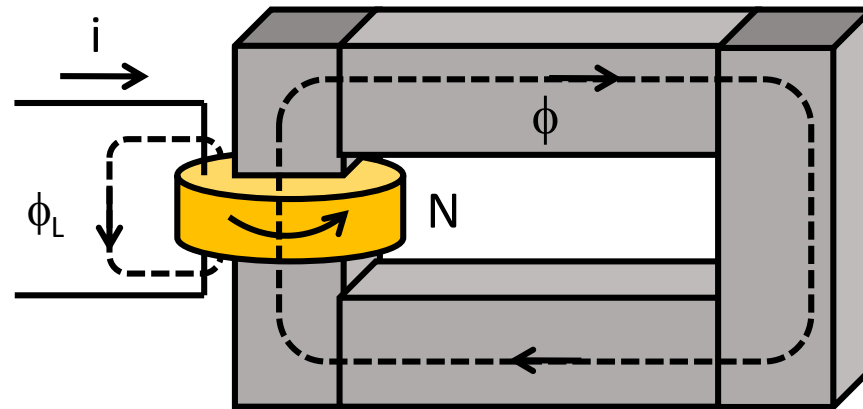
→ Magnetic Circuit Assumptions

- Let magnetic flux be set up by a coil of wire with dc current, i
- Current establishes flux ϕ in the core
- Let there be N turns of wire on the coil



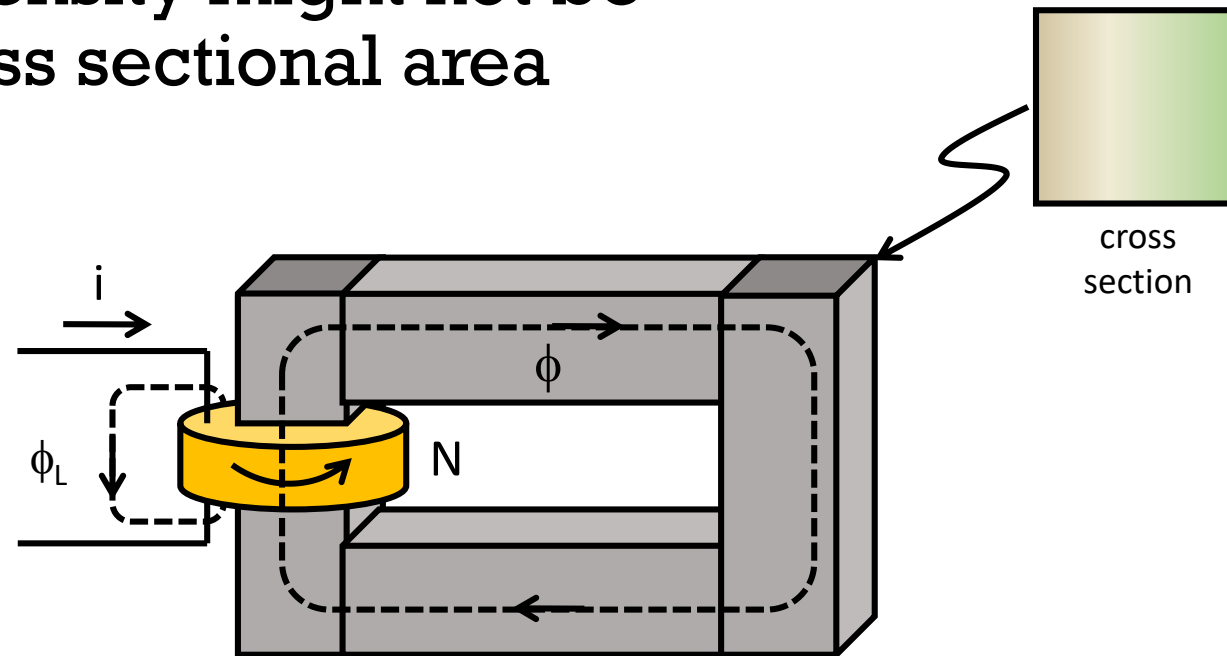
→ Magnetic Circuit Elements

- Some flux does not pass through the core
 - leakage flux: ϕ_L
 - small compared to ϕ
- Leakage flux can be reasonably ignored



→ Magnetic Circuit Elements

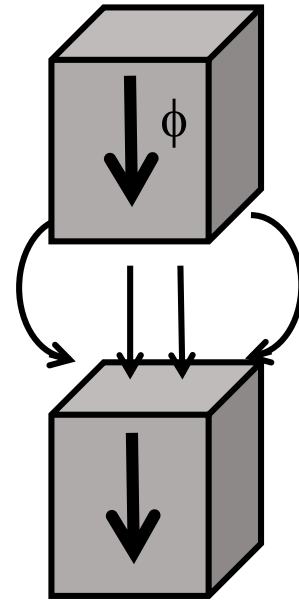
Magnetic flux density might not be uniform in a cross sectional area



→ Magnetic Circuit Elements

- Fringing occurs in air gaps
- Flux density decreases (cross sectional area increases)

Rest of magnetic circuit not shown



→ Magnetic Circuit Assumptions

- Magnetic flux flows entirely through the magnetic material (no leakage)
- Magnet flux density is uniform throughout the cross section the material
- Fringing across air-gaps is negligible

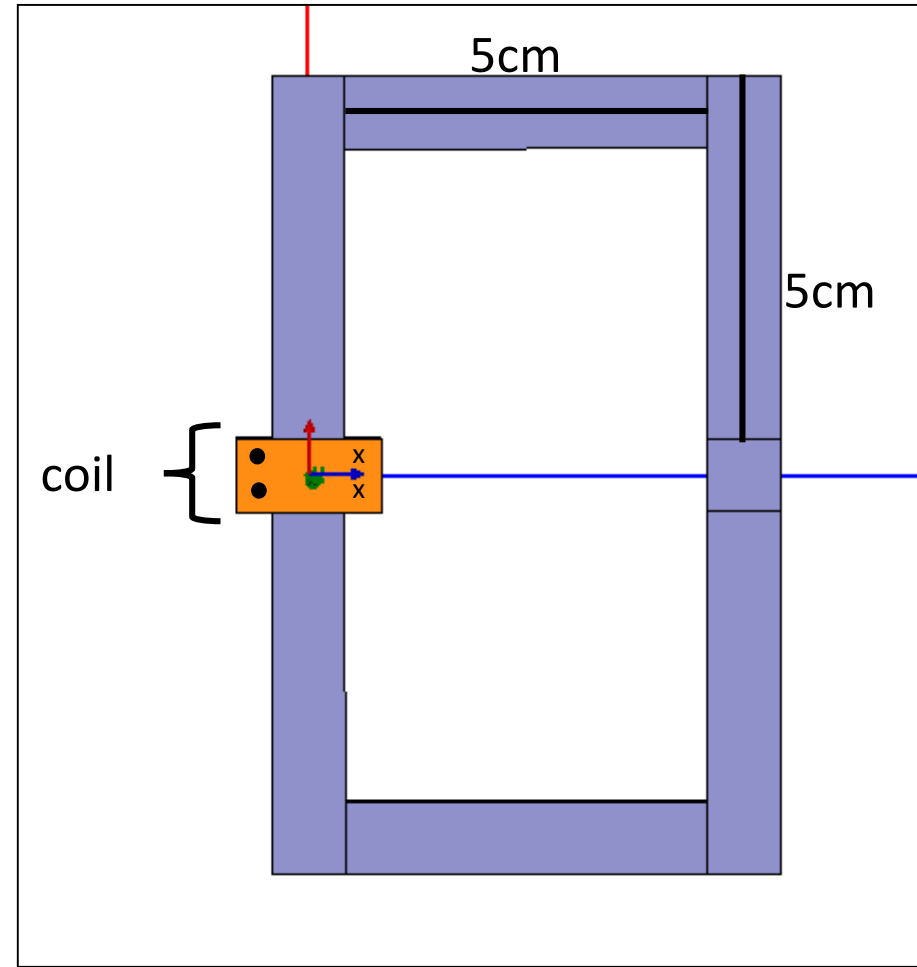
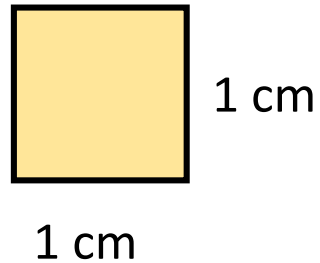
How realistic are these assumptions?

→ Magnetic Circuit Assumptions

Iron yoke with coil of wire

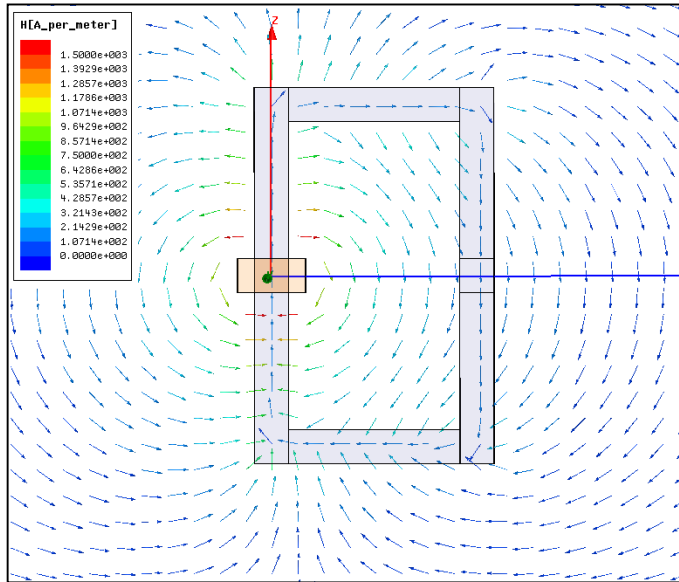
- $\mu_r = 4000$
- 50 A, single turn

yoke cross section



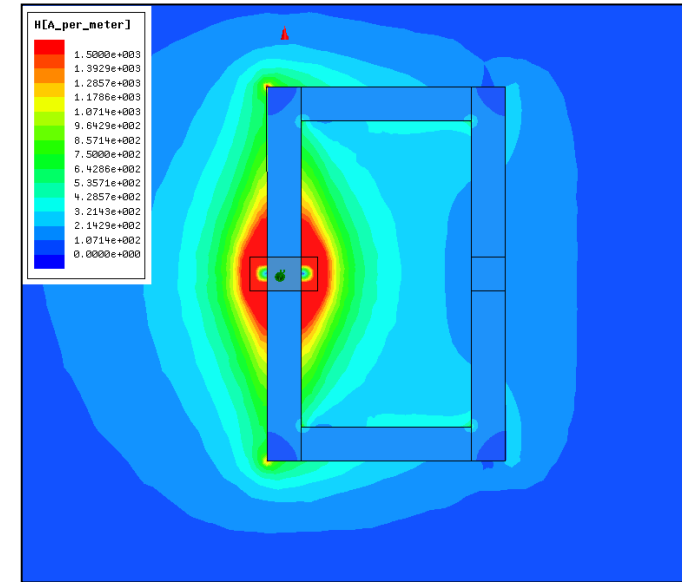
Example Magnetic Circuit

H Field



Iron core influences direction of H field

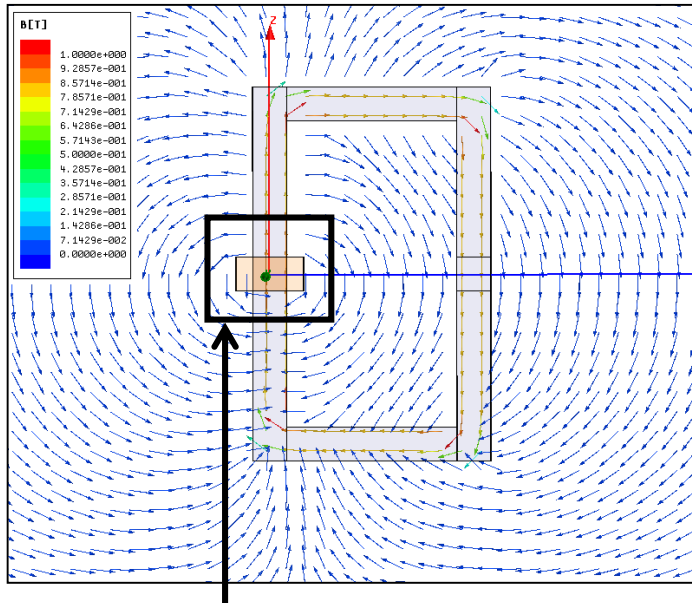
$|H|$



$|H|$ decreases as distance from coil increases

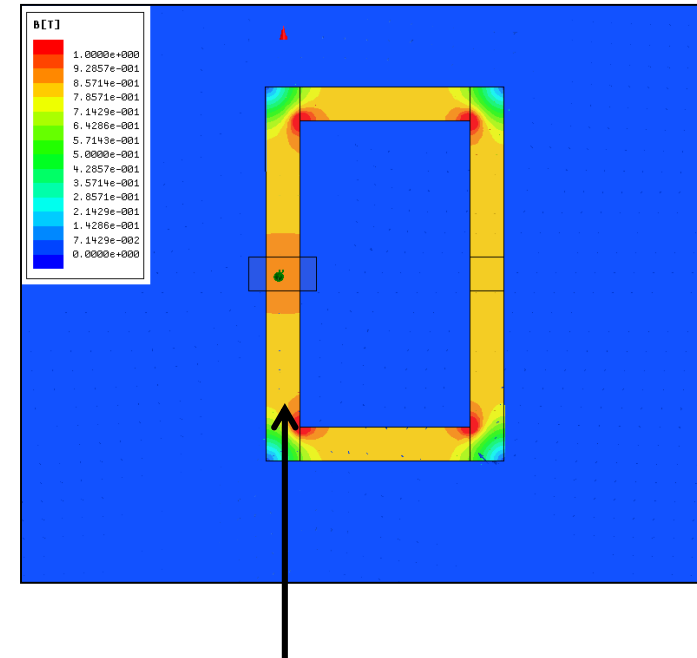
→ Magnetic Circuit Assumptions

B Field



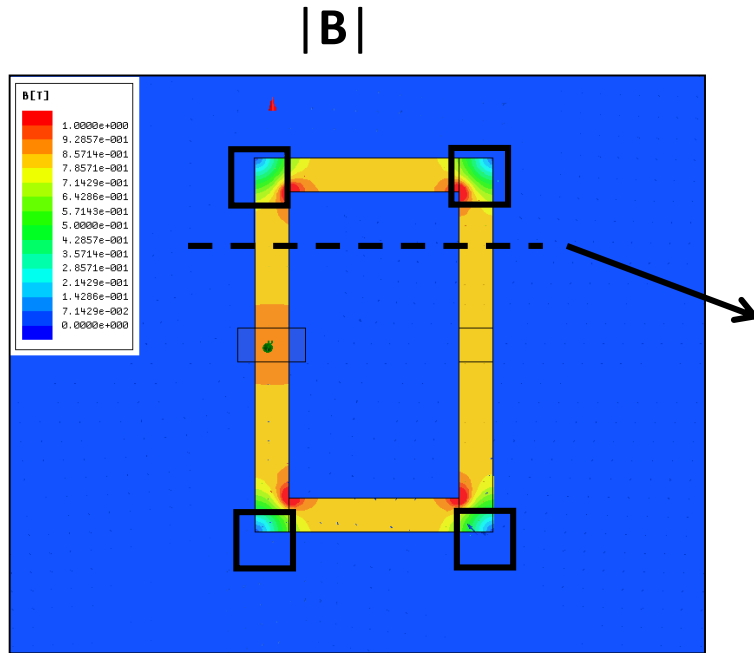
Leakage flux density is small in magnitude

|B|

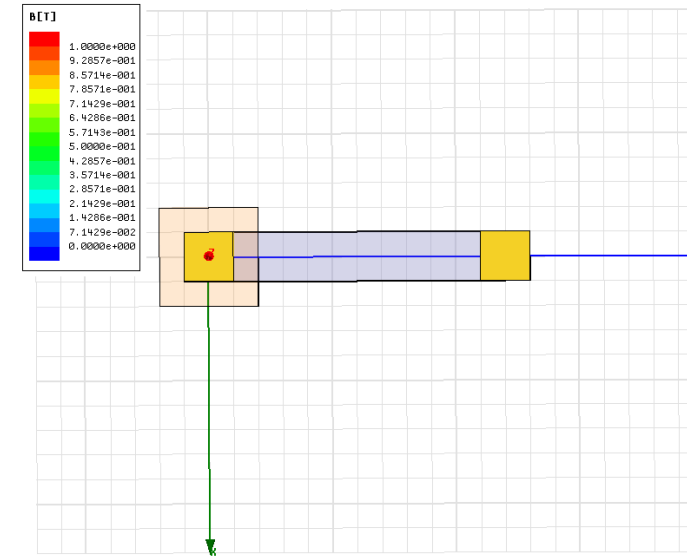


Flux density through the core is much larger than outside it

→ Magnetic Circuit Assumptions



$|B|$ down Z-axis at dashed line



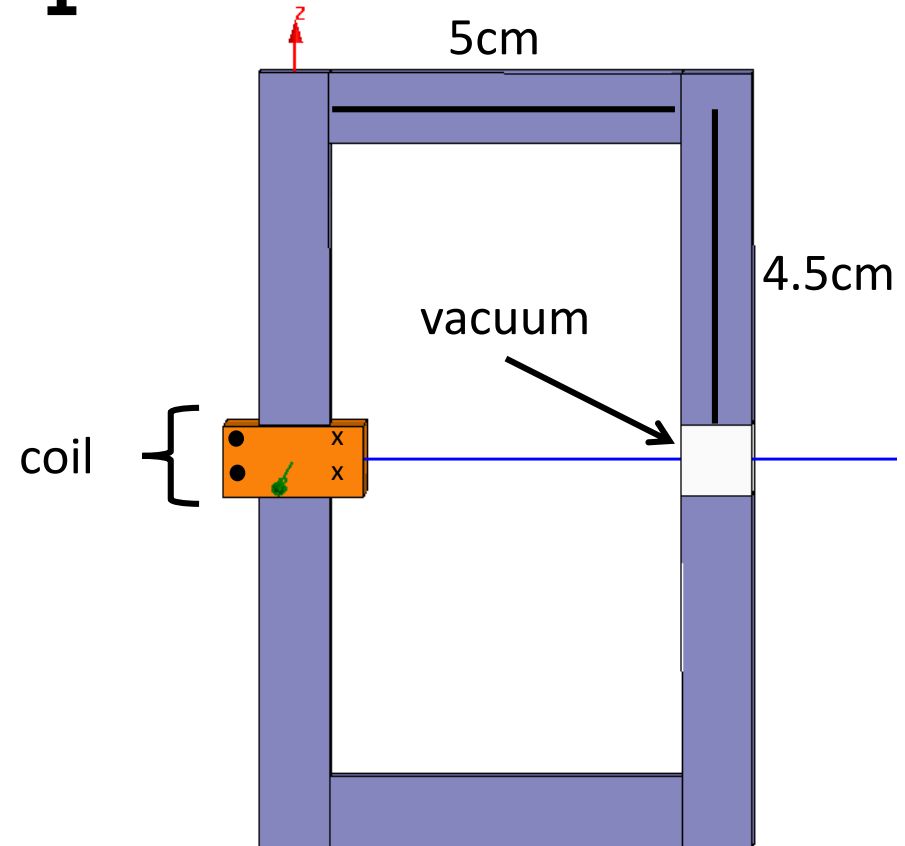
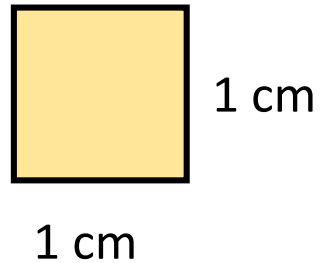
Flux density is nearly uniform

→ Magnetic Circuit Assumptions

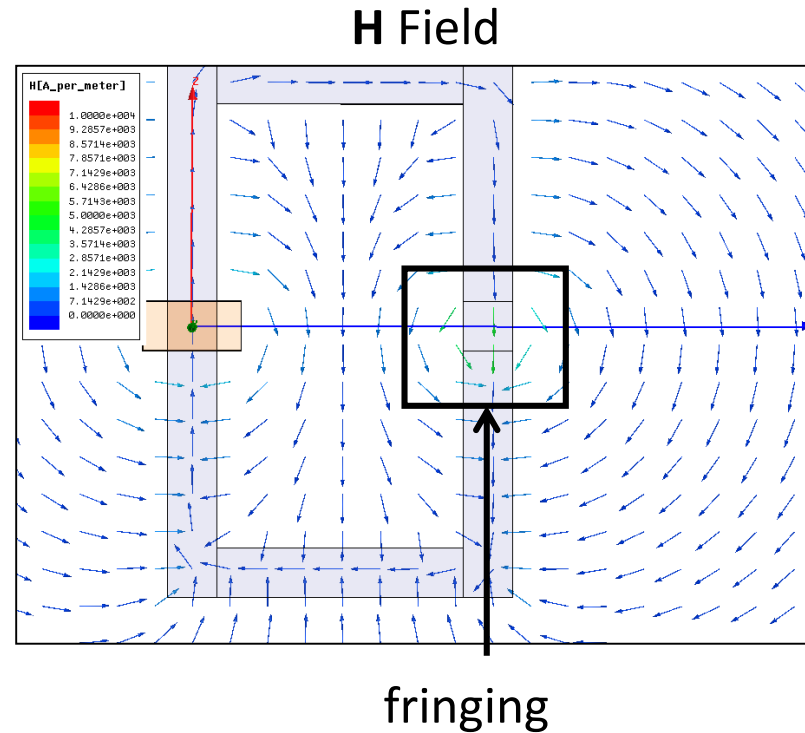
Iron yoke with coil of wire

- $\mu_r = 4000$
- 50 A, single turn

yoke cross section



→ Magnetic Circuit Assumptions

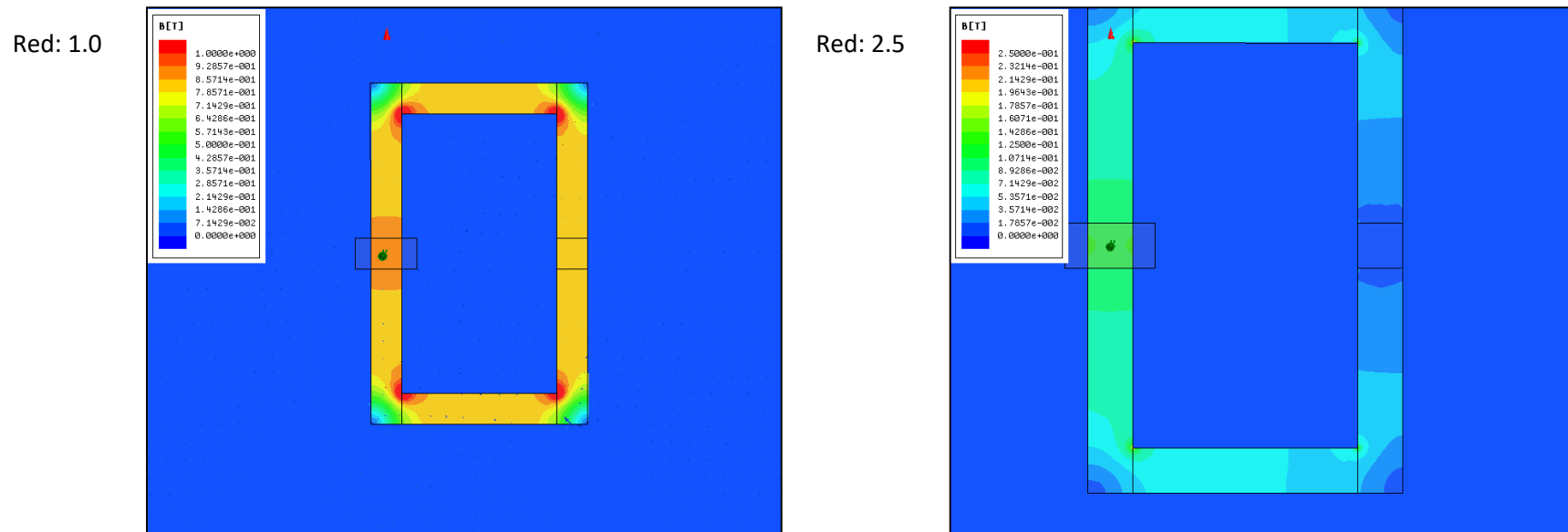


→ Magnetic Circuit Assumptions

- Assumptions hold reasonably well for magnetic circuits
- We next inspect magnetic circuits to develop a qualitative understanding of how **B** and **H** behave

→ Magnetic Circuit Observations

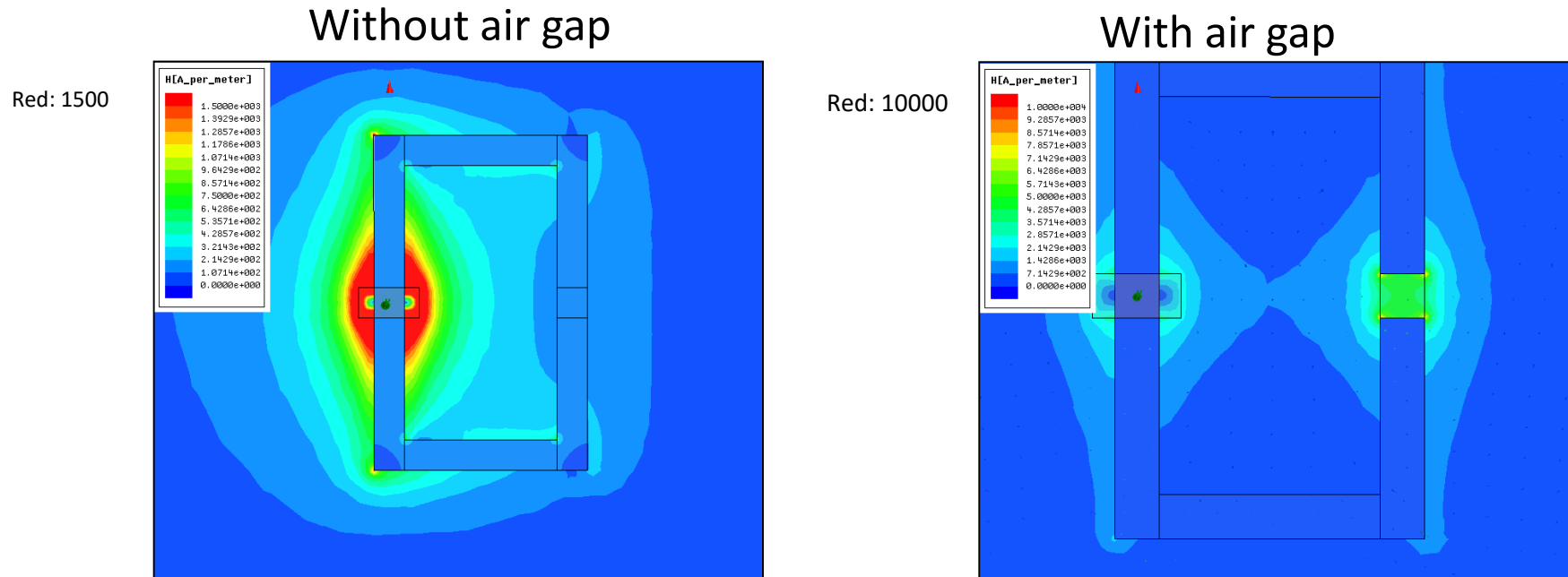
Flux density (flux) is less in a circuit with an air gap



Note: circuits have same dimensions, but the zoom is different.

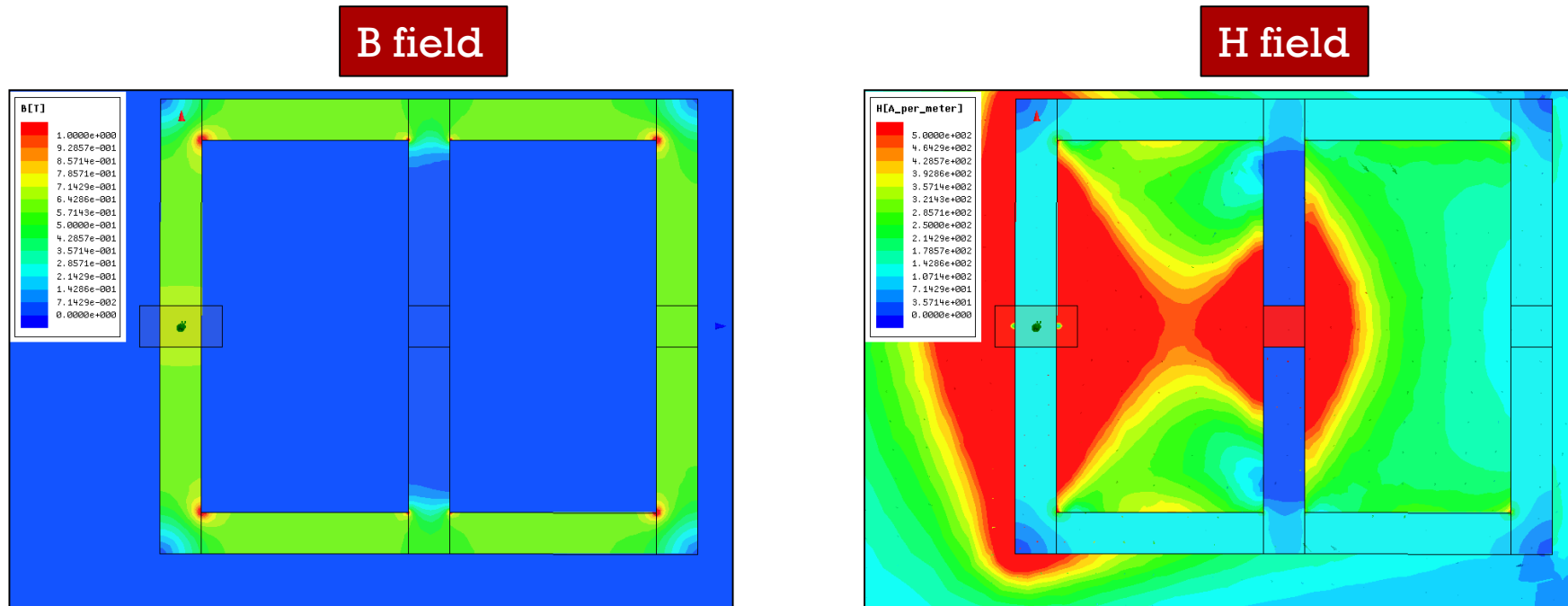
→ Magnetic Circuit Observations

Field intensity is low in iron (high permeability) and high in air gap (low permeability)

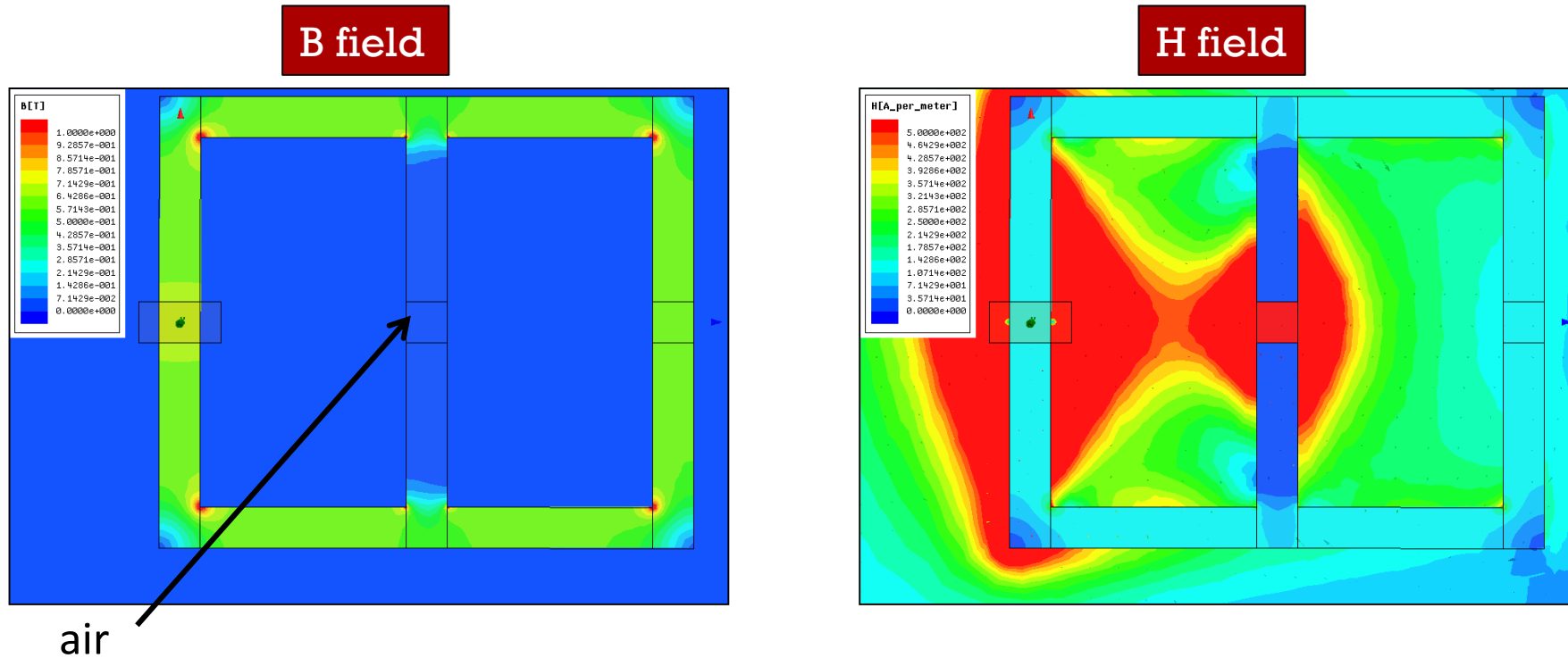


Note: circuits have same dimensions, zoom is different.

→ Magnetic Circuit Observations

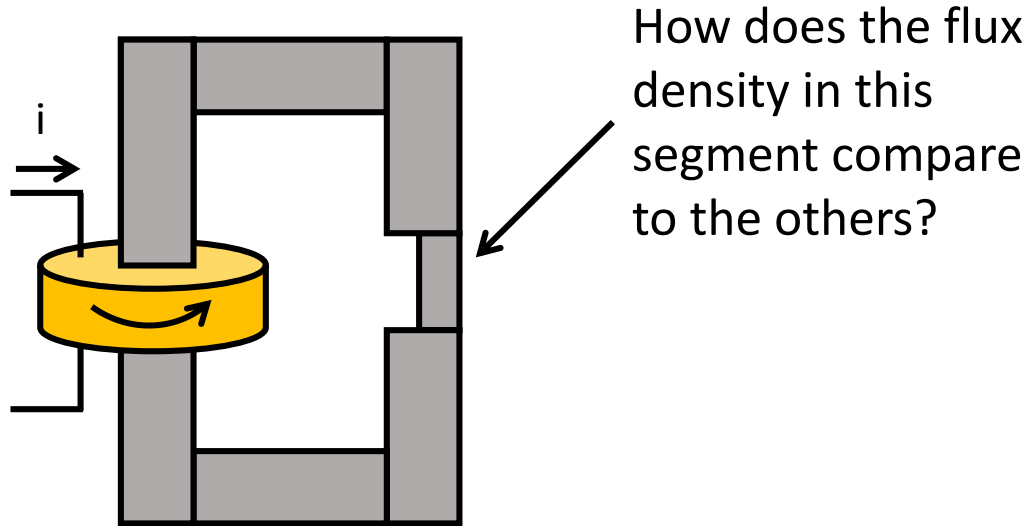


→ Magnetic Circuit Observations



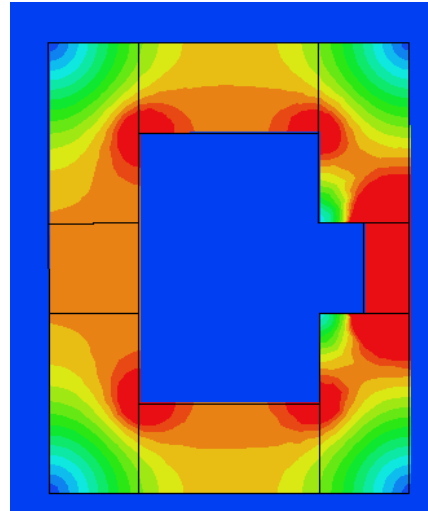
Also note: flux “prefers” path of high permeability.

→ Magnetic Circuit Observations



Assume uniform depth

→ Magnetic Circuit Observations



Summary

- **Basic assumptions for magnetic circuit analysis:**
 - No leakage
 - Uniform flux density
 - No fringing across air-gaps
- **Assumptions are reasonable for most magnetic circuits**