11-Magnetic Circuits

ECEGR 450
Electromechanical Energy Conversion

Overview

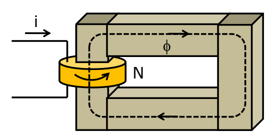
- Introduction
- Magnetic Circuit Assumptions
- Observations of Magnetic Circuits

Introduction

- Faraday's Law and Lorentz force equation are basis for electromechanical energy conversion
  - Both are dependent on flux or flux density
  - How can these quantities be computed for a given physical arrangement?

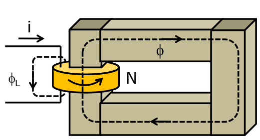
Magnetic Circuit Assumptions

- 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



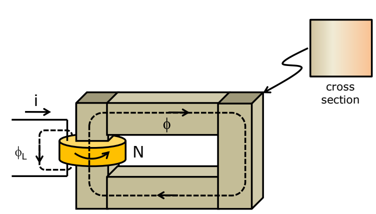
Magnetic Circuit Elements

- 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

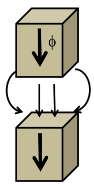
Magnetic flux density may not be uniform in a cross sectional area



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

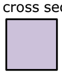
How realistic are these assumptions?

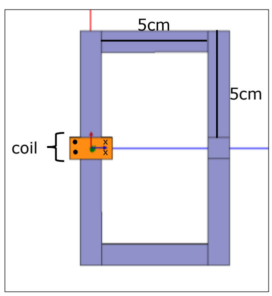
Magnetic Circuit Assumptions

Iron yoke with coil of wire

- μ_r = 4000
- 50 A, single turn

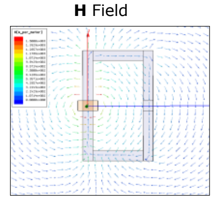
yoke cross section





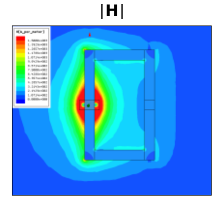
Example Magnetic Circuit

H Field



Iron core influences direction of **H** field

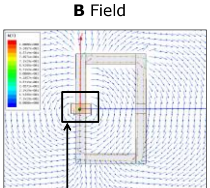
|**H**|



|**H**| decreases as distance from coil increases

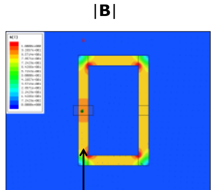
Magnetic Circuit Assumptions

B Field



Leakage flux density is small in magnitude

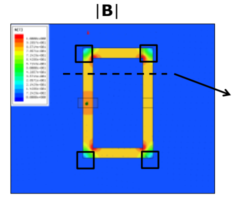
|**B**|



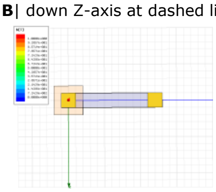
Flux density through the core is much larger than outside it

Magnetic Circuit Assumptions

|**B**|



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

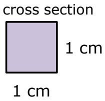


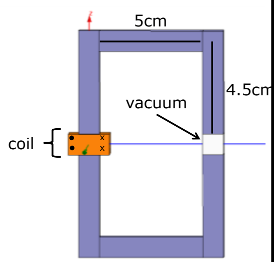
Flux density is nearly uniform

Magnetic Circuit Assumptions

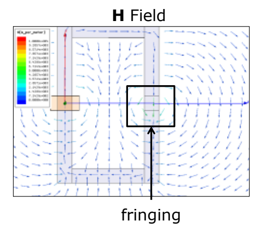
Iron yoke with coil of wire
- μ_r = 4000
- 50 A, single turn

yoke cross section





Magnetic Circuit Assumptions



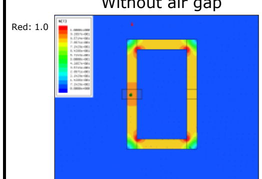
Magnetic Circuit Assumptions

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

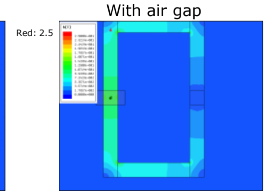
Magnetic Circuit Observations

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

Without air gap



With air gap

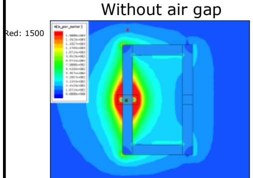


Note: circuits have same dimensions, zoom is different.

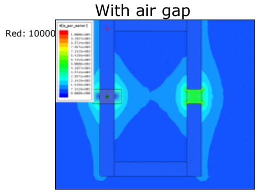
Magnetic Circuit Observations

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

Without air gap



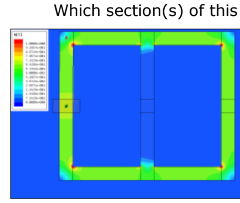
With air gap

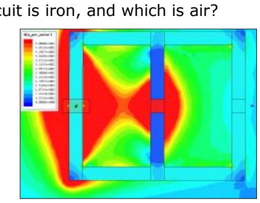


Note: circuits have same dimensions, zoom is different.

Magnetic Circuit Observations

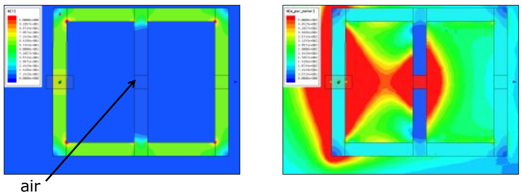
Which section(s) of this circuit is iron, and which is air?





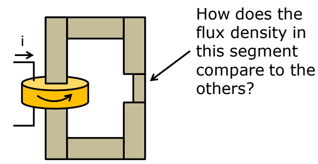
Magnetic Circuit Observations

Which section of this circuit is iron, and which is air?



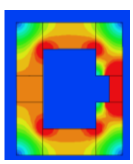
Also note: flux “prefers” path of high permeability.

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