L2a: Other Magnetic Performance Parameters

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Why

Some derived parameters are frequently used for electromagnetic analysis.

In particular, we will consider:

a) Flux Linkage
b) Inductance
c) Capacitance

An understanding of these parameters is important when considering the electronic circuit driving the electromagnetic device

Magnetic Flux and Flux Linkage

Why

Some analysis, particularly in electric motors (Week 3 and 4) relies on the concept of Flux Linkage.

It is important to understand the relationship between Flux, Flux Density, Flux Linkage and Magnetic Vector Potential

How

By replacing B in the integral expression for Flux and then using Stoke's vector identity we can find a closed line integral for Flux.

For FEA, the flux can be found flowing between two points.

Flux Linkage is defined as the product of the number of turns that "Link" the flux and the magnitude of that Flux

$$\phi = \int \mathbf{B} \cdot \mathbf{dS} \quad (6.1)$$

$$\phi = \int (\nabla \times \mathbf{A}) \cdot \mathbf{dS} \quad (6.2)$$

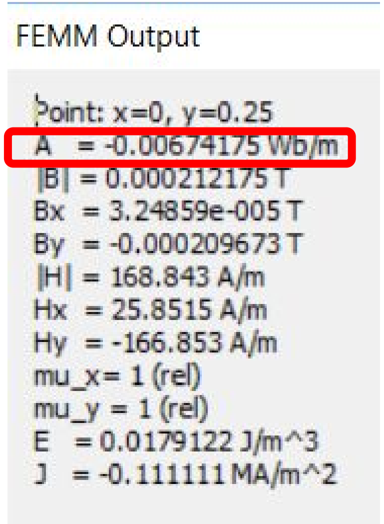
$$\phi = \oint A \cdot dl \quad (6.3)$$

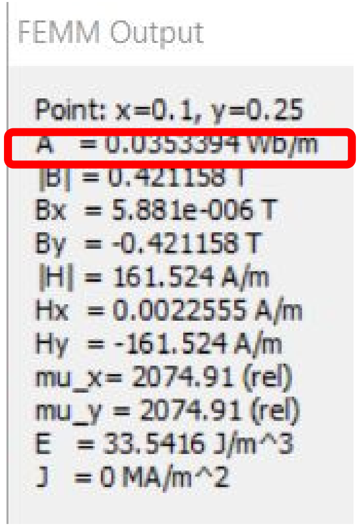
$$\phi_{12} = (A_{z1} - A_{z2})d \quad (6.4)$$

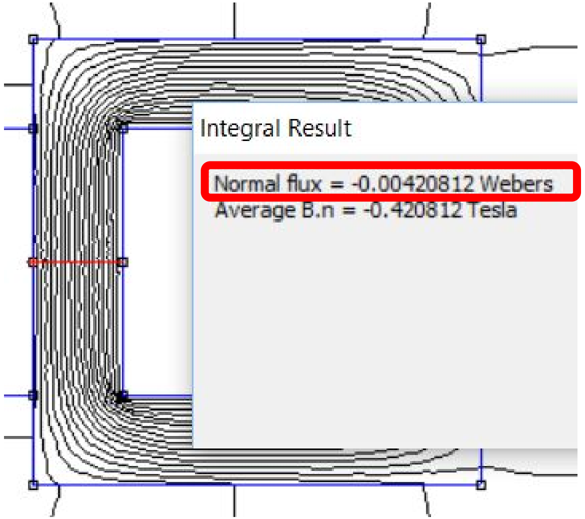
$$\lambda = N\phi \quad (6.5)$$

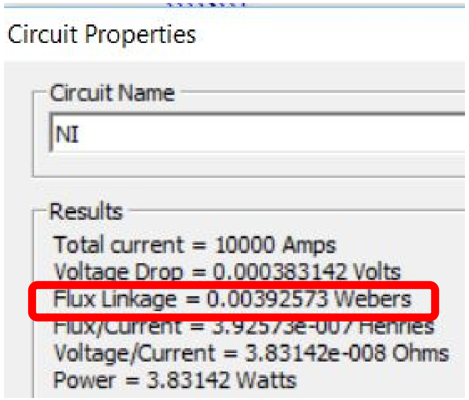
Example 6.1

Example 6.1 Finding Flux in Example 5.3 using Maxwell Given the one-half model of the "C" steel path with airgap of Example 5.3, find the flux passing through the steel pole face using Maxwell finite-element software and compare it with the reluctance solution of Example 3.1.





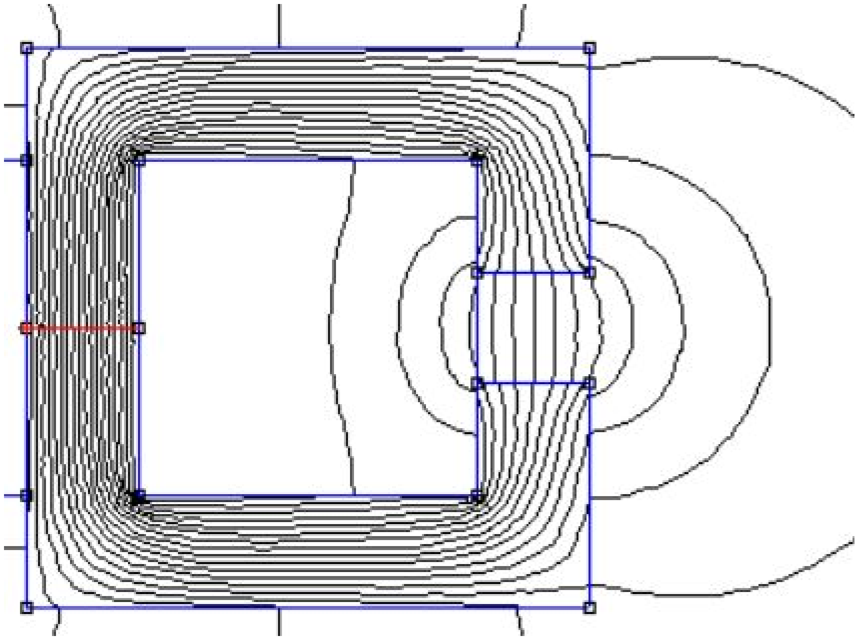




A1`(Wb/m)	A2 (Wb/m)	d (m)	Flux 1-2 (Wb)	Flux - FEMM (Wb)	Flux Linkage - Coil Properties (Wb)
-6.74E-03	3.53E-02	0.1	-4.21E-03	-4.21E-03	3.93E-03

Test for understanding

Why is the Flux Linkage from the coil properties lower then the other calculated flux linkages?



A1`(Wb/m)	A2 (Wb/m)	d (m)	Flux 1-2 (Wb)	Flux - FEMM (Wb)	Flux Linkage - Coil Properties (Wb)
-6.74E-03	3.53E-02	0.1	-4.21E-03	-4.21E-03	3.93E-03

Inductance

Why

Inductance is an important parameter, particularly when considering the external circuit that may control an actuator or motor.

It is a nice way of taking all this “electromagnetic stuff” and creating a simplified model.

How - Inductance

- Inductance is defined as the Flux Linkage created per unit of current
- This can either be the flux linkage created in the same coil (self) or in another coil (mutual)
- If non-linear behaviour needs to be linearised then the two options are:
  - Secant Inductance
  - Incremental inductance

$$L = \lambda / I \; (6.11)$$

$$L_{jk} = \lambda_j / I_k \; (6.12)$$

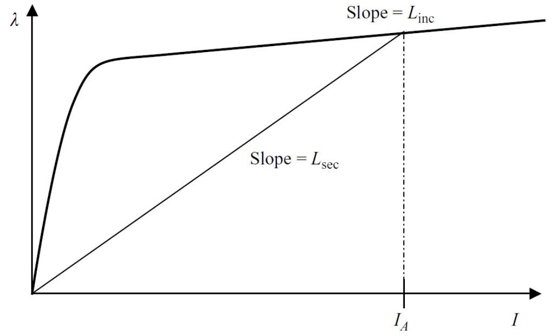


FIGURE 6.3 Inductances L_{sec} (secant) and L_{inc} (incremental) shown as slopes on a typical λ–I curve of a magnetic device.

How - Inductance

Using the definitions for inductance and reluctance, inductance can be shown to be proportional to $\mathbf{N^2}$

$$L = \lambda / I \ (6.11)$$

$$L = N\phi / I \ (6.14)$$

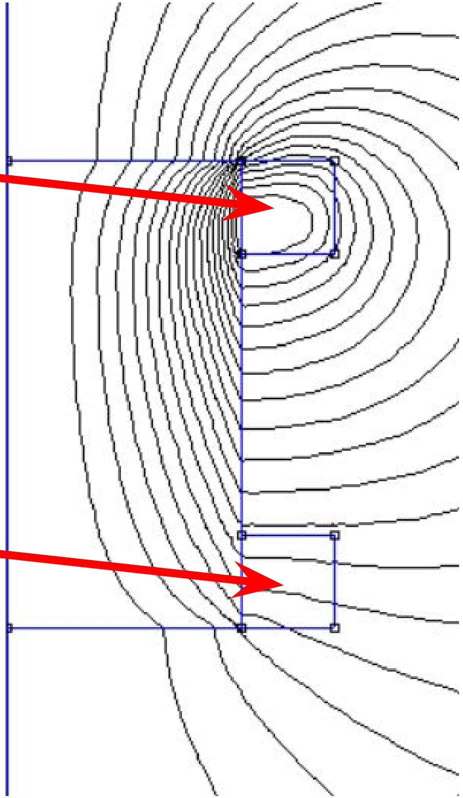
$$\mathscr{R} = NI/\phi \ (6.15)$$

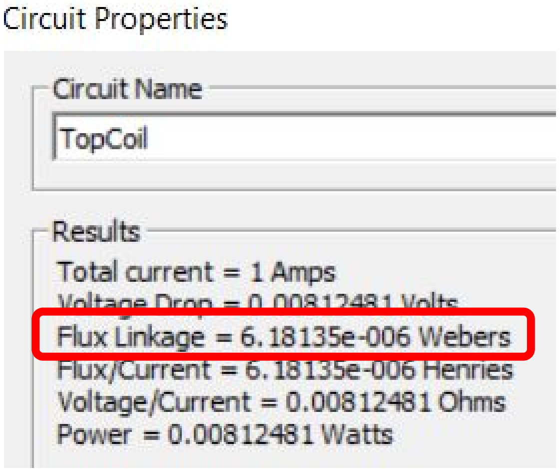
$$L = N^2 / \mathscr{R} \ (6.16)$$

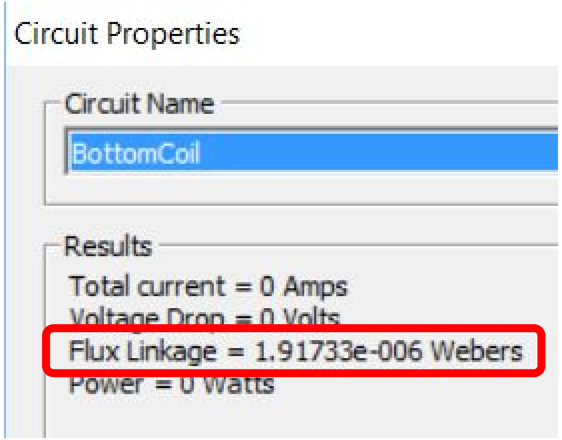
Example 6.3

1A, 10 turns

0A, 10 turns







Test for understanding

What does it indicate if the value for inductance changes with the amount of current?

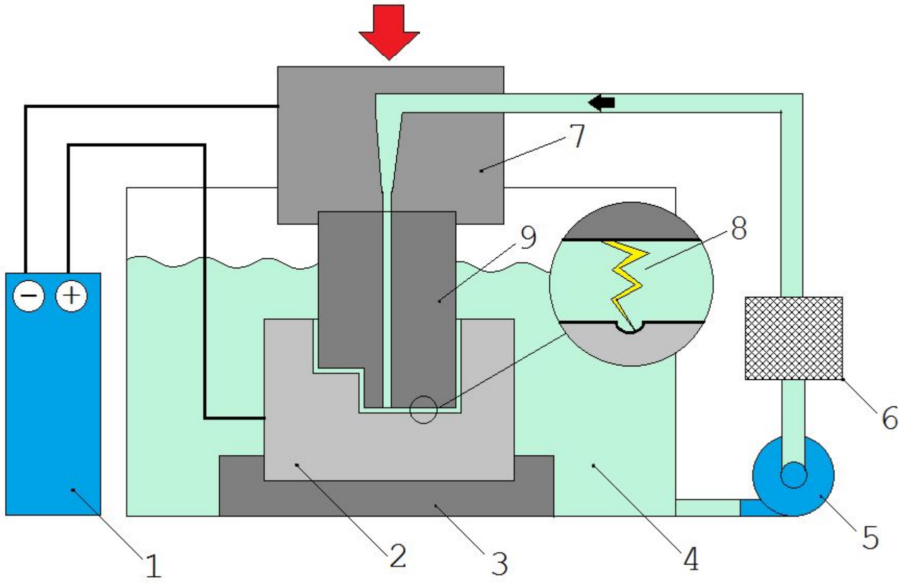
Would you expect this to happen with an “air-core” inductor?

Capacitance

Why

Capacitance effects usually occur at higher frequencies.

We will cover it briefly here for awareness, particularly of bearing currents.



https://commons.wikimedia.org/wiki/File%3AEDM_scheme.png

How

Rather than using the **B, H** and **A** fields we need to use the **D** and **E** fields

$$C = Q/V \quad (6.22)$$

$$W_{\mathrm{el}} = \frac{1}{2}\int \mathbf{D}\cdot\mathbf{E}\,dv = \frac{1}{2}\int \varepsilon E^2 dv = \frac{1}{2}CV^2 \quad (6.23)$$

Example 6.4

Example 6.4 Finding Capacitance using Maxwell Two aluminum plates 2 m wide are separated by 1 m as shown originally in Figure 2.7 and also in Figure E6.4.1. The lower plate is at 0-V DC and the upper at 1 V DC. The region between the two plates is assumed filled with polystyrene, which has a relative permittivity of 2.6. Find the voltage contours, electric field, energy stored, and capacitance using Maxwell. Validate the energy stored using (6.23).

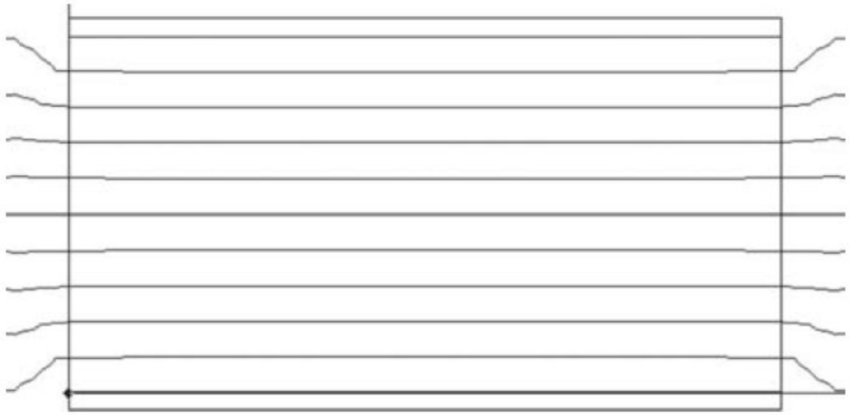


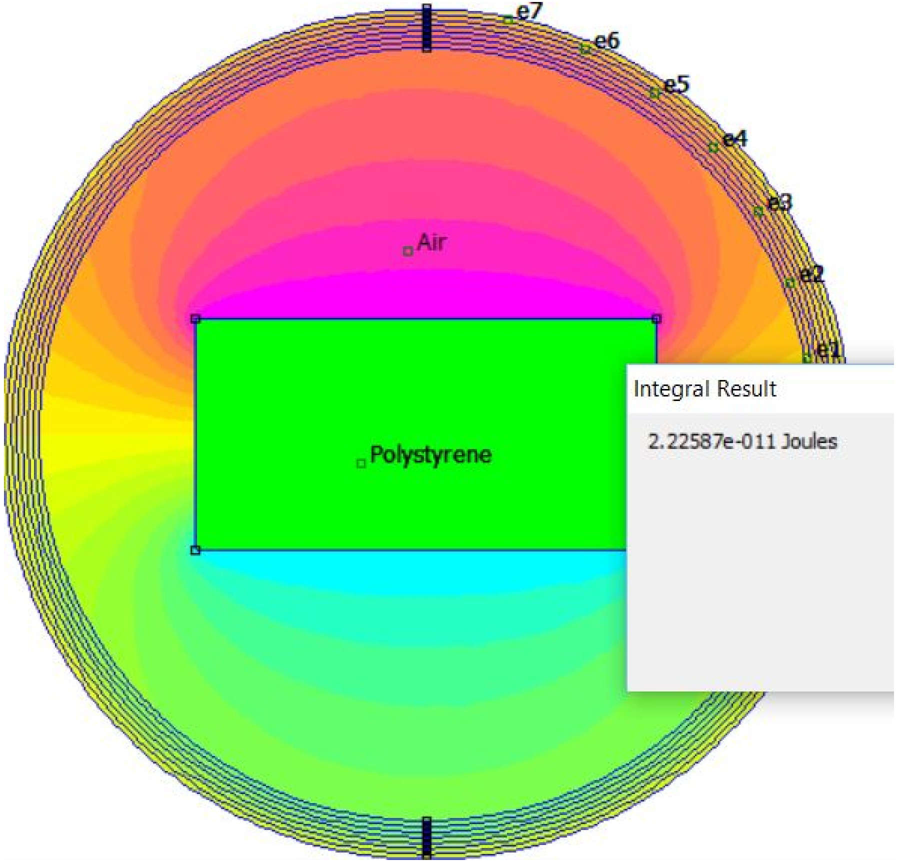
FIGURE E6.4.1 Computer display of capacitor with computed voltage contours.

Example

If the capacitance between two different components can be found then the entire motor can be modelled using an equivalent "spice" network

$$W_{el} = 2.41\text{E}{-}11 = \frac{1}{2}CV^2 = 0.5\text{ C} \quad \text{(E6.4.2)}$$

$$C = 2(2.41\text{E}{-}11) = 48.2\text{pF} \quad \text{(E6.4.3)}$$



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