Magnetic circuits

The source of magnetic flux is current. Not just current, but the product of current and the number of times the current is wrapped around a core—NI. The units for NI are ampere-turns (At). This quantity, magnetomotive force (MMF), is analogous to voltage in electric circuits.

$$\mathbf{F} = NI$$

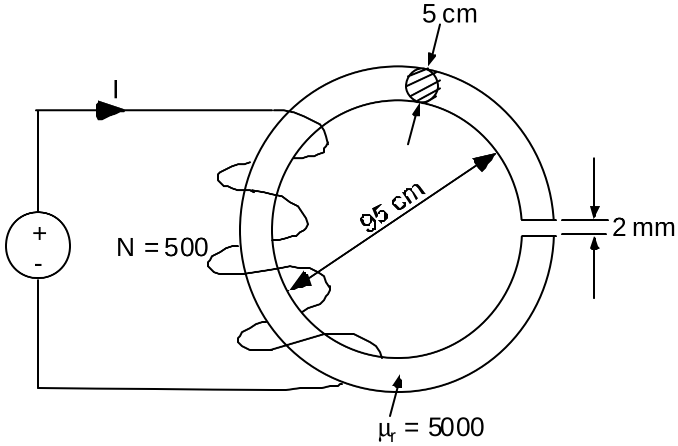
Magnetic flux, ϕ, plays the role of current. By convention, the pole from which magnetic flux leaves is called the north pole and the one to which it enters is called the south pole. The earth is a notable exception!

In magnetic circuits, reluctance, $\mathcal{R}$, plays the role that resistance does in electric circuits. Like resistance, reluctance is determined by material property and geometry.

The inductance of a coil is determined by the core's reluctance and the number of turns.

$$L = N^2/\mathcal{R}$$

Example



i) Find the current needed to produce a flux of 5 mWb in the air-gap.

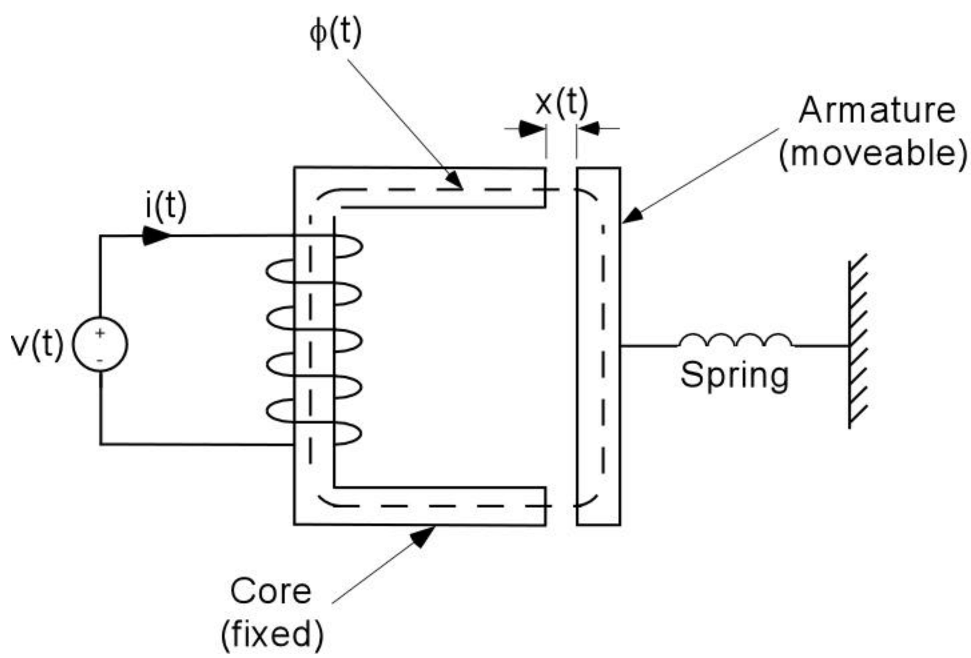
ii) What is the direction of the flux in the core based on the shown direction of the current.

iii) Determine the inductance of the coil.

Relays and solenoids

These are devices that produce mechanical movement from an electrical signal. Its basic components are:

i) **coil**, which, when connected to a supply, creates the MMF which is the source of magnetic flux in the core.
ii) **core**, which carries the flux from the coil to the air-gap (sometimes more than one air-gap is used). The core is usually fixed and has a low reluctance.
iii) **armature**, which carries the flux between the air-gaps. It is movable and, like the core, has a low reluctance. The armature is usually connected to the mechanical device that has to be actuated e.g. shut-off valve.
iv) **spring**, which holds the armature in the non-actuated position.



In the ideal case the reluctance of the steel in the core and armature is negligible, this means that all MMF is dropped across the two air-gaps which are in series.

$$R = 2\,R_g$$

The magnetic circuit is

The energy stored by an inductance is

$$E = \frac{1}{2} L i^2$$

Using this to find the energy stored in each air gap.

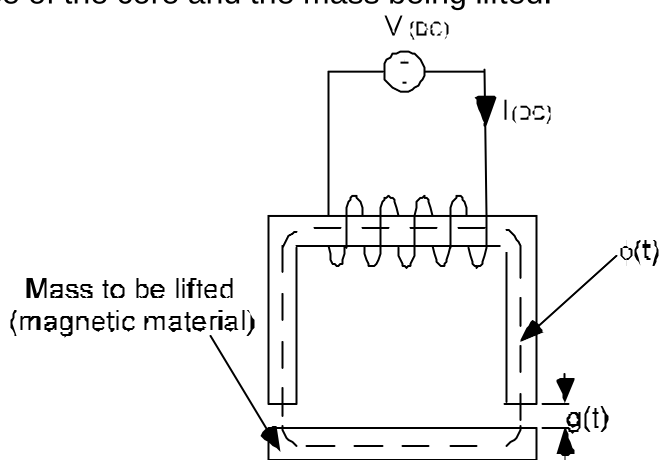
Now, taking the derivative with respect to the gap, usually denoted as x or g, the force per air gap is obtained.

Example

For the relay shown previously, the spring exerts a force of 0.2 N. The gap length is 5mm when fully open and 2mm when fully closed. The coil has 5000 turns and is wound on a core of 1cm square cross section. Predict the pick-up and drop-out currents.

Example

A lifting magnet is shown on the left. The core has a square cross-section of 6 x 6 cm^2. The coil has 300 turns and a resistance of 6Ω. Determine the lifting force when the air-gap is 5mm and a 120V DC supply is used. Neglect the reluctance of the core and the mass being lifted.



Example

Repeat with a 120 V 60 Hz, AC supply, instead of DC.

The reactance of the AC coil reduces the current which greatly reduces the lifting force. Lifting magnets are nearly always DC.