Magnetic Circuit

What is magnetic circuit? "A path followed by a magnetic flux"

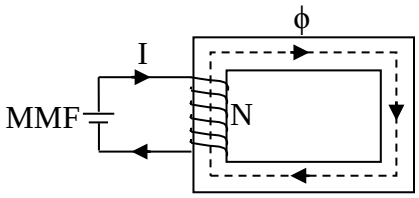
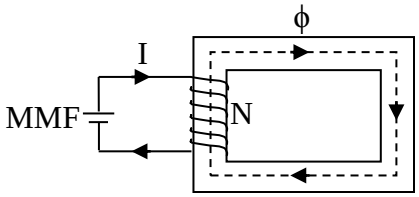
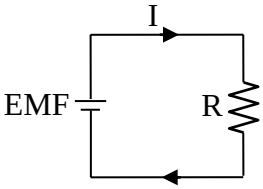


Fig. 1

MMF =Magneto Motive Force
=NI AmpTurns (AT); N = No of turns
Φ = Flux
S = Reluctance

Comparison between magnetic and electric circuit: Similarities

S.No	Quantity	Magnetic Circuit	Electric Circuit
1	**Definition**	 "Path followed by a magnetic flux is called magnetic circuit"	 "Path followed by an electric current is called electric circuit"
2	**Driving Force**	MMF=Magneto Motive Force =NI (AT)	EMF=Electro Motive Force (Volts)
3	**Response**	$\text{Flux}(\varphi l = \frac{\text{MMF}}{\text{Reluctance (S)}}$ Weber	$\text{Curretn(I)} = \frac{\text{EMF}}{\text{Resistance (R)}}$ Amp
4	**Impedance**	Reluctance $S = \frac{1}{\mu}\frac{l}{a}$ AT/Wb μ = Permeability	Resistance $R = \rho\frac{l}{a}$ (Ω)
	In Series	$S=S_1+S_2+S_3+\ldots$	$R=R_1+R_2+R_3+\ldots$
	In Parallel	$\frac{1}{S}=\frac{1}{S_1}+\frac{1}{S_2}+\frac{1}{S_3}+\ldots$	$\frac{1}{R}=\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}+\ldots$
5	**Admittance**	Permeance = 1/S	Conductance =1/R
6	**Density**	Flux Density $B=\frac{\phi}{a}\ Wb/m^2$	Current Density $J=\frac{I}{a}\ A/m^2$
7	**Flux Intensity**	Magnetic flux intensity $H=\frac{MMF}{l}\ (AT/m)$	Electric current density $E=\frac{EMF}{l}\ (Volts/m)$
8	**Drop**	MMF drop = ϕS	Voltage drop =IR

Dissimilarities between magnetic and electric circuit:

S.No	Magnetic Circuit	Electric Circuit
1	Magnetic flux does not actually flow in magnetic circuit	Current does flow in an electric circuit.
2	There is no insulator for magnetic flux	There are insulator as well as good conductor for an electric current
3	Permeability (μ) depends on flux(ϕ)	Resistivity (ρ) is independent of current (I)
4	Residual flux persists after removal of MMF	There is no current after removal of EMF
5	There is no wastage of energy due to reluctance (S)	Energy is dissipated in resistance (R)

<u>Magnetic Circuits with their electrical equivalent circuit:</u>

1. **Simple Magnetic circuit:**

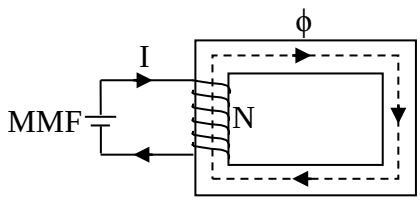


Fig. 2a

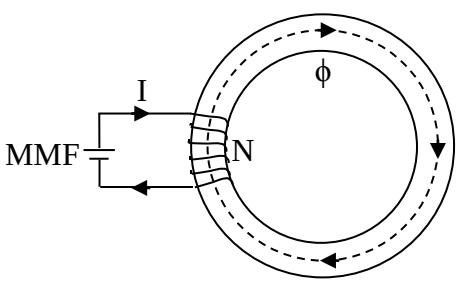


Fig. 2b

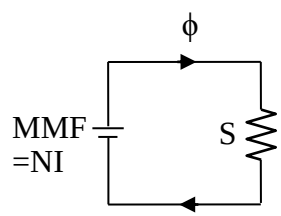


Fig. 2c Electrical Equivalent Circuit

$$MMF = \phi S$$

$$S = \frac{1}{\mu_0 \mu_r} \frac{l}{a}$$

Where l = Mean length of iron core
a = X-sectional are of iron core through which flux is passing

2. **Magnetic Circuit with air gap:**

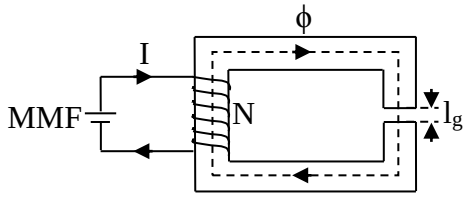


Fig. 3a

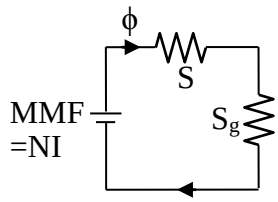


Fig. 3b Electrical Equivalent Circuit

$$MMF = \phi(S + S_g)$$

$$S = \frac{1}{\mu_0 \mu_r}\frac{l}{a} \quad \& \quad S_g = \frac{1}{\mu_0}\frac{l_g}{a_a}$$

Where l_g = Mean length of air gap
a_g = X-sectional are of the air gap through which flux is passing

3. Parallel Magnetic Circuit:

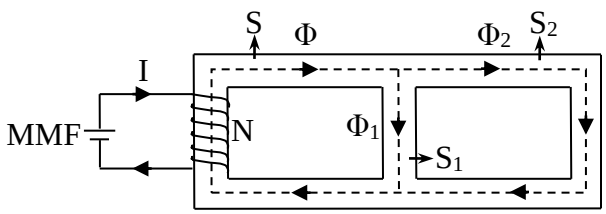


Fig. 4a

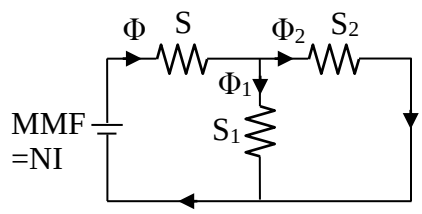


Fig. 4b Electrical Equivalent Circuit

$$MMF = \phi S + \phi_1 S_1$$

$$\phi_1 S_1 - \phi_2 S_2 = 0 \quad KVL\ in\ RHS\ loop$$

4. Composite Magnetic Circuit:

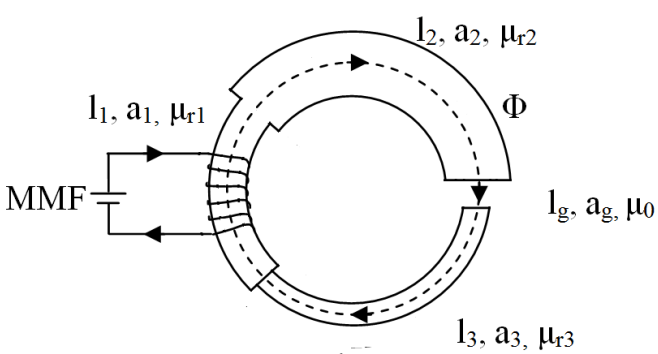


Fig. 4a

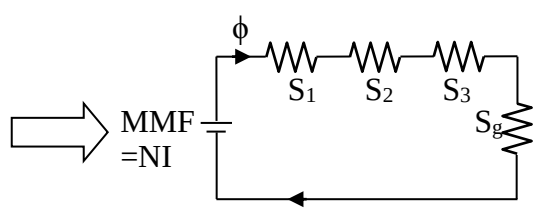


Fig. 4b Electrical Equivalent Circuit

Fringing: Useful flux passing though air gap tends to bulge out in the air gap as shown in figure 5, therefore increasing the area of air gap and reducing the flux density. This effect is known as fringing.

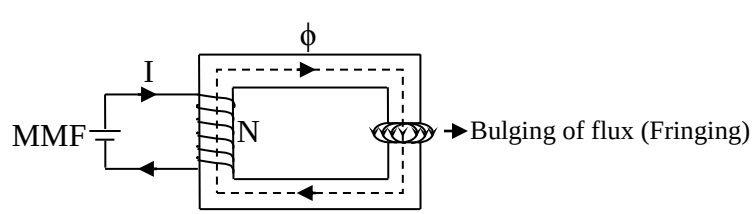


Fig. 5

Leakage flux: The flux which doesn't follow the desired path is known as leakage flux.

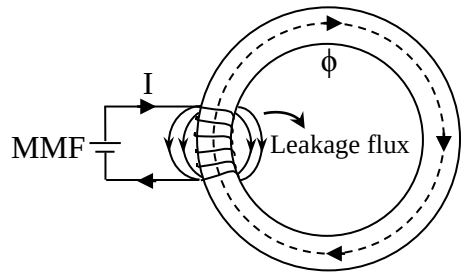


Fig. 6

Let Φ = Useful flux
Φ_t = Total flux created
Then

$$Leakage\ Factor = \frac{Total\ Flux}{Useful\ Flux} = \frac{\phi_t}{\phi} \geq 1$$

Example 1: A rectangular magnetic core shown in fig.7 has square cross-section of area 16 cm^2. An air gap of 2 mm is cut across one of its limbs. Find the exciting current needed in the coil having 1000 turns wound on the core to create an air gap flux of 4 mWb. The relative permeability of the core is 2000.

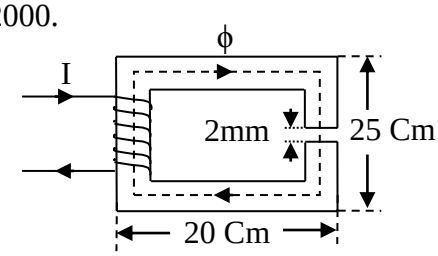


Fig. 7

Solution:

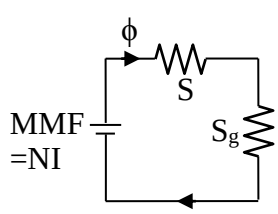


Fig. 7a Electrical Equivalent Circuit

$$S = \frac{1}{\mu_0 \mu_r}\frac{l}{a} = \frac{1}{4\pi \times 10^{-7} \times 2000}\frac{(2\times 16 + 2\times 21 - 0.2)\times 10^{-2}}{16\times 10^{-4}} = 1.835\times 10^5$$

$$S_g = \frac{1}{\mu_0}\frac{l_g}{a_g} = \frac{1}{4\pi\times10^{-7}}\frac{0.2\times10^{-2}}{16\times10^{-4}} = 9.947\times10^5$$

$$Total\ \ AT \quad NI = \phi S + \phi S_g$$

$$1000I = 4\times10^{-3}(1.835\times10^5 + 9.947\times10^5) \Rightarrow I = 4.7\ A$$

Example 2: A magnetic core shown in fig.8 has square cross-section of area 2x2 cm^2. Find the total AT and exciting current needed in the coil having 500 turns so that flux in right limb is 2 mWb. The relative permeability of the core is 600.

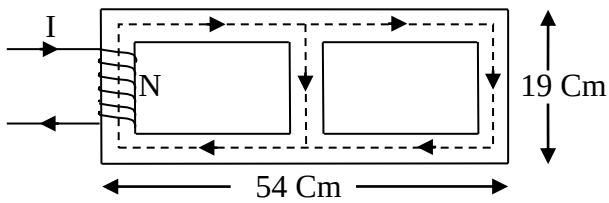


Fig. 8

Solution:

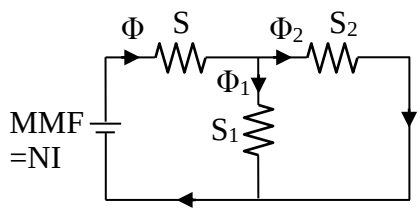


Fig. 8b Electrical Equivalent Circuit

$$S = S_2 = \frac{1}{\mu_0\mu_r}\frac{l}{a} = \frac{1}{4\pi\times10^{-7}\times600}\frac{(2\times26+2\times17)\times10^{-2}}{2\times2\times10^{-4}} = 28.516\times10^5$$

$$S_1 = \frac{1}{\mu_0\mu_r}\frac{l_1}{a_1} = \frac{1}{4\pi\times10^{-7}\times600}\frac{17\times10^{-2}}{2\times2\times10^{-4}} = 5.6369\times10^5$$

$$\phi_1 S_1 = \phi_2 S_2 \Rightarrow \phi_2 = \frac{S_1}{S_2}\phi_1 = 0.3953\ mWb$$

$$\phi = \phi_1 + \phi_2 = 2.3953\ mWb$$

Total AT (NI) $= \phi S + \phi_2 S_2$ Or $= \phi S + \phi_1 S_1$

$= 7957.6$ AT

NI $= 7957.6 \Rightarrow I = 15.91$ A

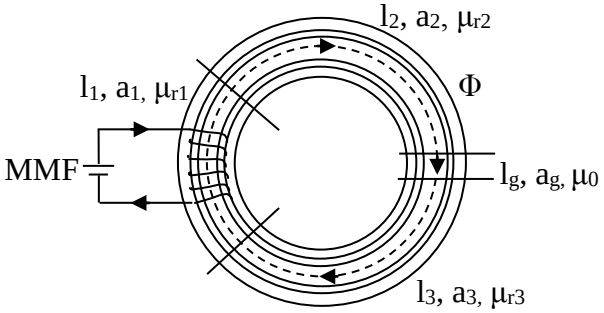


Fig. 4a