

## Magnetic Circuit

**What is magnetic circuit?** “A path followed by a magnetic flux”

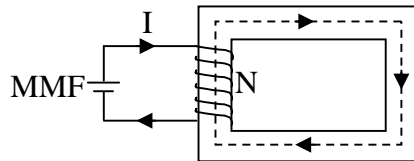
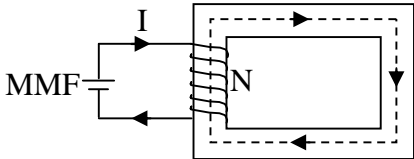
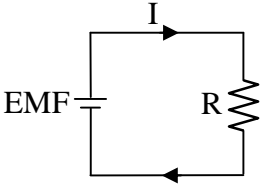


Fig. 1

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

### Comparison between magnetic and electric circuit:

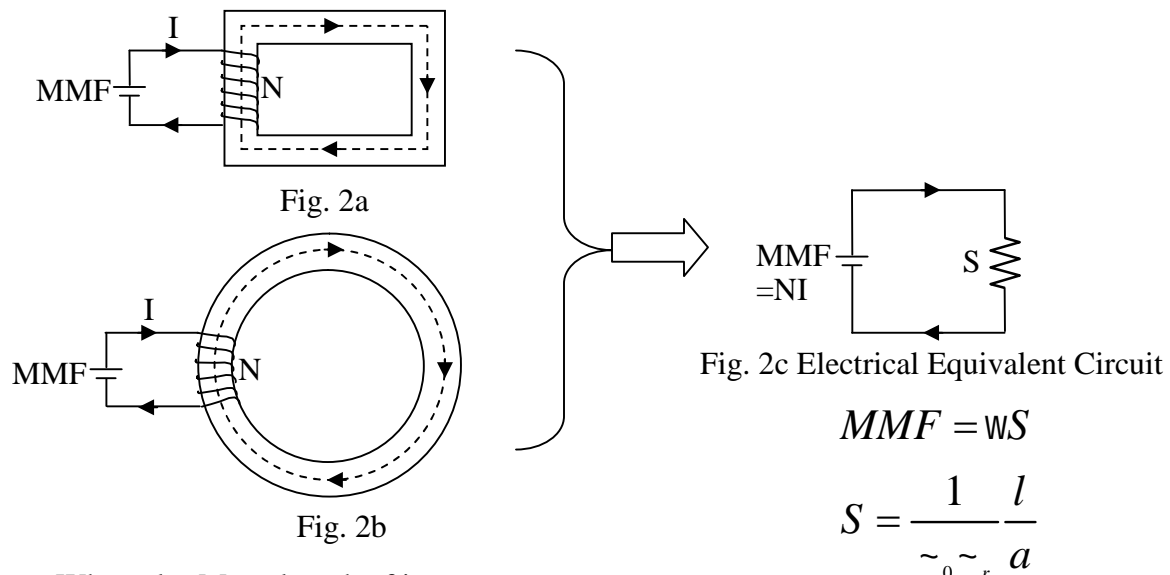
S.No	Quantity	Magnetic Circuit	Electric Circuit
1	Definition	 “Path followed by a magnetic flux is called magnetic circuit”	 “Path followed by an electric current is called electric circuit”
2	Driving Force	MMF=Magneto Motive Force =NI (AT)	EMF=Electro Motive Force (Volts)
3	Response	Flux( $\phi$ ) = $\frac{\text{MMF}}{\text{Reluctance}(S)}$ Weber	Current(I) = $\frac{\text{EMF}}{\text{Resistance}(R)}$ Amp
4	Impedance	Reluctance $S = \frac{l}{\mu a}$ AT/Wb [ $\mu$ = Permeability	Resistance $R = \dots \frac{l}{a}$ ( $\Omega$ )
	In Series	$S = S_1 + S_2 + S_3 + \dots$	$R = R_1 + R_2 + R_3 + \dots$
	In Parallel	$\frac{1}{S} = \frac{1}{S_1} + \frac{1}{S_2} + \frac{1}{S_3} + \dots$	$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$
5	Admittance	Permeance = 1/S	Conductance = 1/R
6	Density	Flux Density $B = \frac{\phi}{a}$ Wb/m <sup>2</sup>	Current Density $J = \frac{I}{a}$ A/m <sup>2</sup>
7	Flux Intensity	Magnetic flux intensity $H = \frac{\text{MMF}}{l}$ (AT/m)	Electric current density $E = \frac{\text{EMF}}{l}$ (Volts/m)
8	Drop	MMF drop = S	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 ( $\mu$ ) depends on flux( )	Resistivity ( ) 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 (R)	Energy is dissipated in resistance (R)

**Magnetic Circuits with their electrical equivalent circuit:**

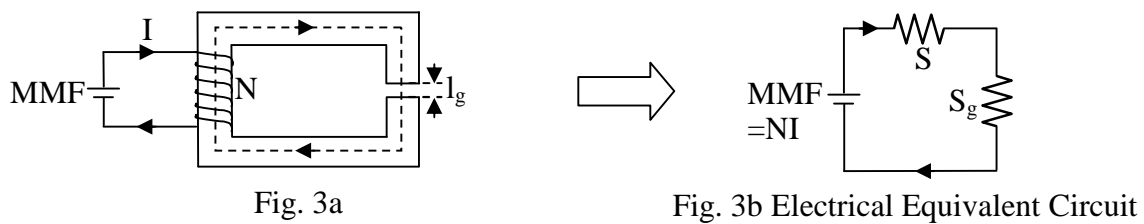
**1. Simple Magnetic circuit:**



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:**



$$MMF = w(S + S_g)$$

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

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:

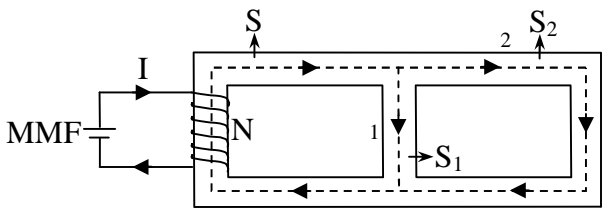


Fig. 4a

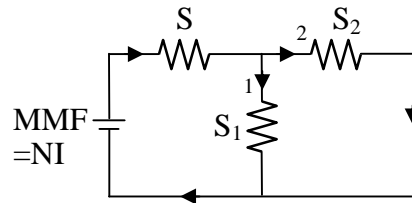


Fig. 4b Electrical Equivalent Circuit

$$MMF = wS + w_1 S_1$$

$$w_1 S_1 - w_2 S_2 = 0 \quad \text{KVL in RHS loop}$$

### 4. Composite Magnetic Circuit:

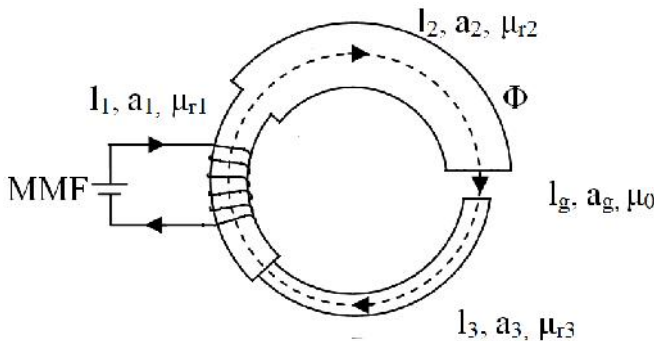


Fig. 4a

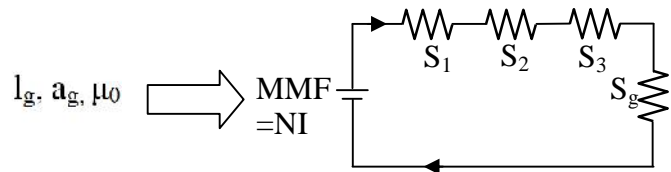


Fig. 4b Electrical Equivalent Circuit

**Fringing:** Useful flux passing through 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.

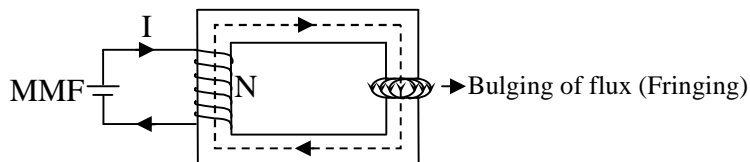


Fig. 5

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

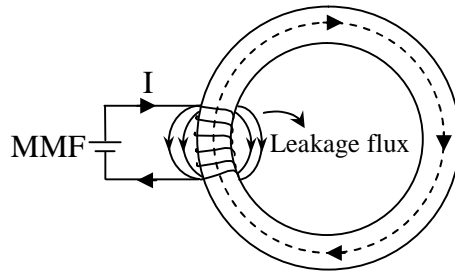


Fig. 6

Let  $\phi_w$  = Useful flux  
 $\phi_t$  = Total flux created

Then

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

**Example 1:** A rectangular magnetic core shown in fig.7 has square cross-section of area  $16 \text{ cm}^2$ . An air gap of  $2 \text{ mm}$  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  $4 \text{ mWb}$ . The relative permeability of the core is 2000.

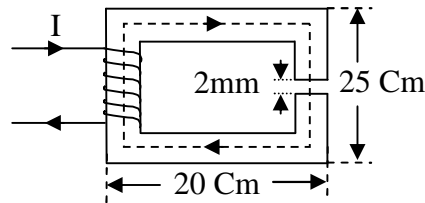


Fig. 7

Solution:

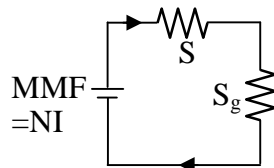


Fig. 7a Electrical Equivalent Circuit

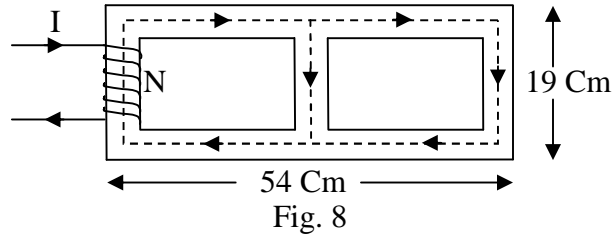
$$S = \frac{1}{\mu_0 \mu_r} \frac{l}{a} = \frac{1}{4\pi \times 10^{-7} \times 2000} \frac{(2 \times 16 + 2 \times 21 - 0.2) \times 10^{-2}}{16 \times 10^{-4}} = 1.835 \times 10^5$$

$$S_g = \frac{1}{\mu_0} \frac{l_g}{a_g} = \frac{1}{4\pi \times 10^{-7}} \frac{0.2 \times 10^{-2}}{16 \times 10^{-4}} = 9.947 \times 10^5$$

$$\text{Total AT} \quad NI = \mu S + \mu S_g$$

$$1000I = 4 \times 10^{-3} (1.835 \times 10^5 + 9.947 \times 10^5) \Rightarrow I = 4.7 \text{ A}$$

**Example 2:** A magnetic core shown in fig.8 has square cross-section of area  $2 \times 2 \text{ cm}^2$ . 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.



Solution:

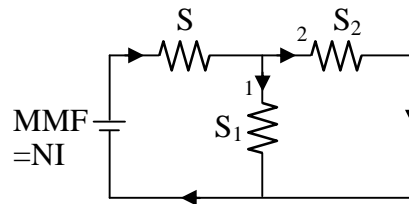


Fig. 8b Electrical Equivalent Circuit

$$S = S_2 = \frac{1}{\mu_0 \mu_r} \frac{l}{a} = \frac{1}{4\pi \times 10^{-7} \times 600} \frac{(2 \times 26 + 2 \times 17) \times 10^{-2}}{2 \times 2 \times 10^{-4}} = 28.516 \times 10^5$$

$$S_1 = \frac{1}{\mu_0 \mu_r} \frac{l_1}{a_1} = \frac{1}{4\pi \times 10^{-7} \times 600} \frac{17 \times 10^{-2}}{2 \times 2 \times 10^{-4}} = 5.6369 \times 10^5$$

$$w_1 S_1 = w_2 S_2 \Rightarrow w_2 = \frac{S_1}{S_2} w_1 = 0.3953 \text{ mWb}$$

$$w = w_1 + w_2 = 2.3953 \text{ mWb}$$

$$\begin{aligned} \text{Total AT (NI)} &= S + S_2 & \text{Or} &= S + S_1 \\ &= 7957.6 \text{ AT} \\ \text{NI} &= 7957.6 \Rightarrow I = 15.91 \text{ A} \end{aligned}$$