Module 3 : Magnetic Circuits 4 Hrs

Electromagnetic Induction: Self and mutual; Magnetically coupled circuits; Series and parallel magnetic circuits; Dot convention

Course Outcome (CO2)

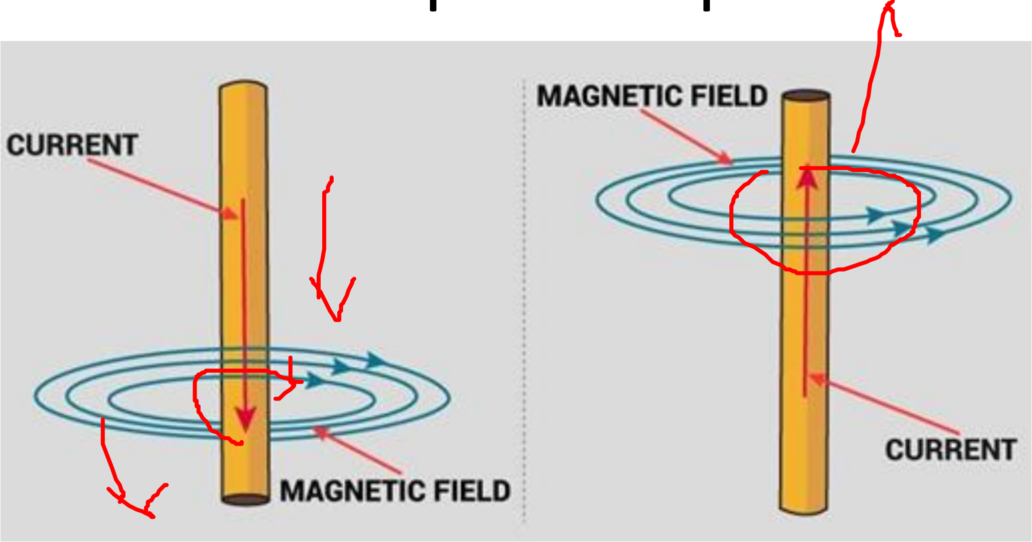
Analyze the parameters of magnetically coupled circuits and compare various types of electrical machines

Magnetic effect of electric current

When an electric current flows through a conductor, magnetic field is set up all along the conductor's length.

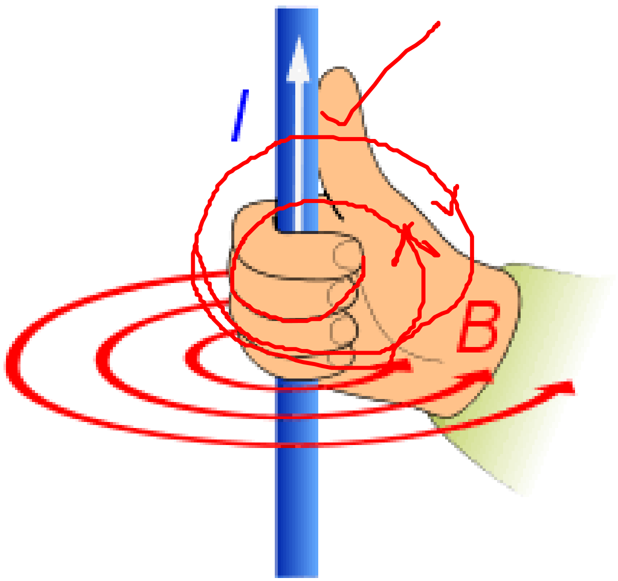
The magnetic lines of force are in the form of concentric circles around the conductor.

The direction of lines of force depends upon the direction of current.



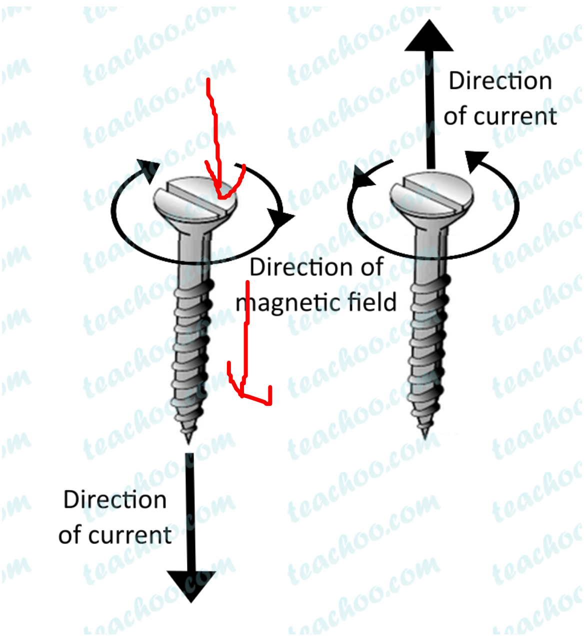
Right hand gripping/thumb rule

Hold the conductor in the right hand with the outstretched thumb pointing in the direction of current. Then the other fingers point in the direction of the magnetic field around the conductor.



The right hand cork screw rule

The direction of the magnetic field is the direction of rotation of a right handed corkscrew turned so as to advance along the wire in the current direction.

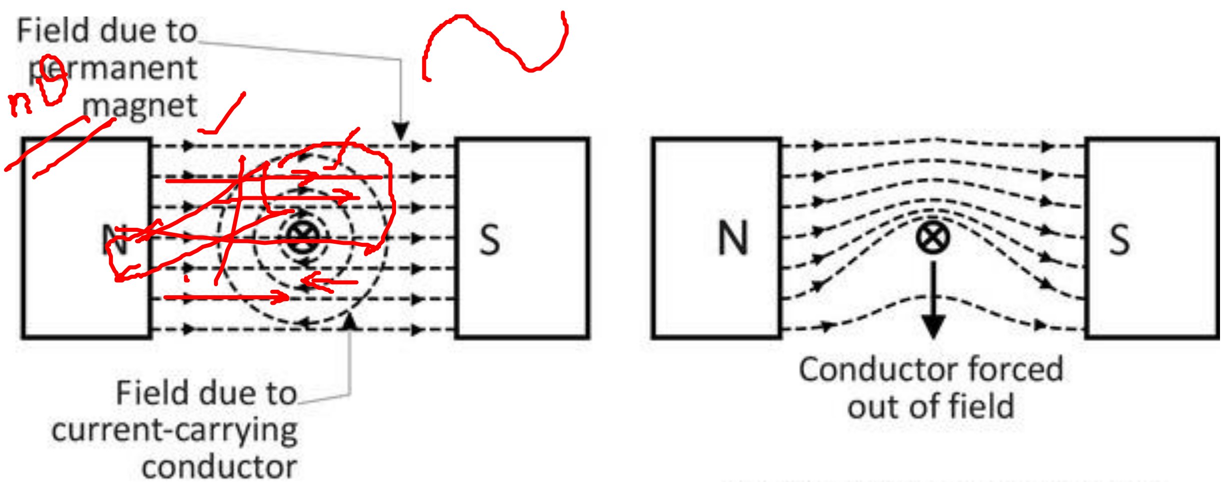


Current carrying conductor in magnetic field

- Consider a current carrying conductor placed at right angles to a magnetic field.
- By the law of interaction, the conductor experiences a force which acts in a direction perpendicular to both the field and the current.

$F = BlI \sin\theta$

$F = BIl$

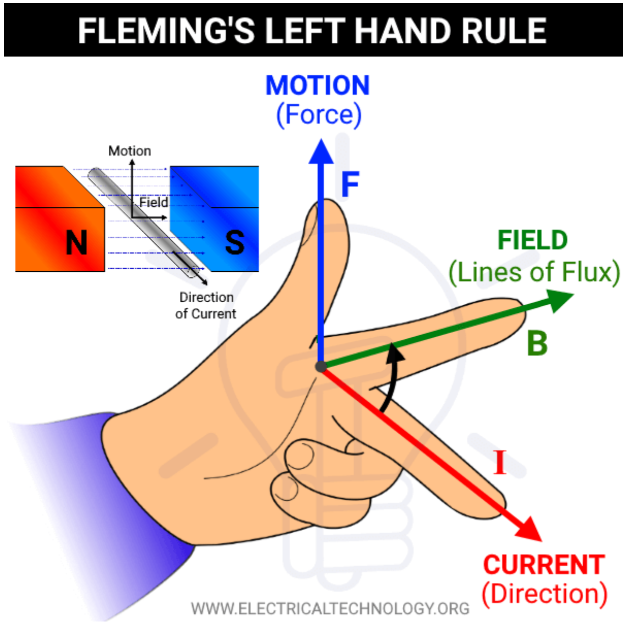


(a) Individual Fields

(b) Combined Fields Causing Force on Conductor

Fleming’s left hand rule

Stretch out the fore finger, middle finger and thumb of the left hand so that they are at right angles to one another. If the fore finger points in the direction of magnetic field (north to south) and the middle finger points towards the direction of current, then the thumb will point in the direction of motion of the conductor.



Law of electromagnetic induction

Faraday's law:

Whenever the magnetic flux linking a conductor changes an emf is always induced in it. The magnitude of such an emf is proportional to the rate of change of flux linkages.

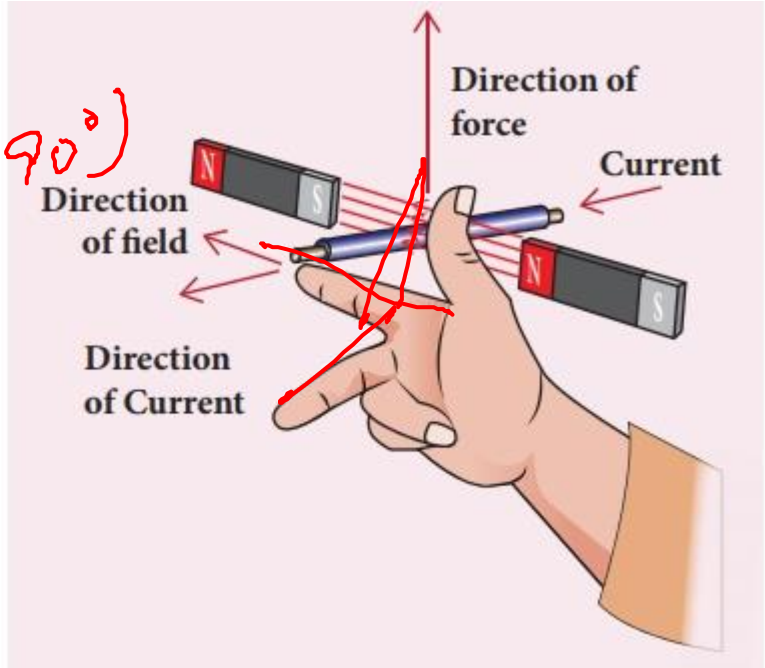
Lenz's law:

The law states that any induced emf will circulate a current in such a direction so as to oppose the cause producing it.

Fleming's right hand rule

Hold the thumb, the fore finger and the middle finger of the right hand at right angles to one another. If the thumb points to the direction of motion and the fore finger to the direction of the magnetic field, the middle finger will point the direction of current.

$$e = B l v \sin\theta$$
$$= B l v \quad (\theta = 90^\circ)$$



Induced emf

Dynamically induced emf:

The conductor is moved in a stationary magnetic field in such a way that there is a magnitude change in flux linkages. This kind of induced emf is known as dynamically induced emf (Ex. generator).

Statically induced emf:

The conductor is stationary and the magnetic field is moving or changing. This kind of induced emf is known as statically induced emf (Ex. transformer).

Self induced emf

Mutually induced emf

Simple problems

A conductor 10 cm long and carrying a current of 60 A lies perpendicular to a field of strength 1000 A/m. Calculate

$F = BIl$

(a) the force acting on the conductor

(b) the mechanical power to move this conductor against this force with a speed of 1 m/s

(c) emf induced in the conductor.

Simple problems

$$F = BIl$$

$$H = 1000\ A/m$$

$$B = \mu H$$

$$= \mu_0 \mu_r H \quad (\mu_r = 1)$$

$$B = 4\pi \times 10^{-7} \times 1000$$

$$= 4\pi \times 10^{-4}\ Wb/m^2$$

$$F = 4\pi \times 10^{-4} \times 60 \times 0.1$$

$$= 7.5 \times 10^{-3}\ N$$

$$= 7.5\ mN$$

Simple problems

① $F = 7.5 \times 10^{-3}\ N$

② Mech. Power $= F \times v$

$= 7.5 \times 10^{-3} \times 1$

$= 7.5 \times 10^{-3}\ W$

$= 7.5\ mW$

③ emf $e = Blv$

$= 4\pi \times 10^{-4} \times 0.1 \times 1$

$= 1.25 \times 10^{-4}\ V$

Simple problems

An air cored toroidal coil has 480 turns, a mean length of 30 cm and a cross-sectional area of 5 cm^2. Calculate

(a) the inductance of the coil and

(b) the average induced emf, if a current of 4 A is reversed in 60 ms.

$-4A$

$N = 480 \quad l = 30\,cm = 0.3\,m \quad A = 5\,cm^2$

$= 5 \times 10^{-4}\,m^2$

Simple problems

$N = 480$ $l = 30\,cm = 0.3\,m$

$A = 5\,cm^2 = 5 \times 10^{-4}\,m^2$

$\mu_0 = 4\pi \times 10^{-7}$

$MMF = NI = \phi S = Hl$

$H = NI/l$

$B = \mu H = \mu \frac{NI}{l}$

$\phi = BA = \frac{\mu_0 N I A}{l}$

$L = \frac{N\phi}{I} = \frac{\mu_0 N^2 A}{l} = \frac{\mu_0 \mu_r N^2 A}{l}$

$H = A/m$ ✓

$H = \frac{MMF}{l}$

$= AT/m$

✓ $= A/m$

Simple problems

$$L = \frac{\mu N^2 A}{l} = \frac{\mu_0 \mu_r N^2 A}{l}$$

$$= \frac{4\pi \times 10^{-7} \times 480^2 \times 5 \times 10^{-4}}{0.3}$$

$$= 4.82 \times 10^{-4} \text{ H}$$

$$= 0.482 \times 10^{-3} \text{ H}$$

$$= 0.482 \text{ mH}$$

$$= 482 \text{ } \mu\text{H}$$

Simple problems

$L = 0.482 \times 10^{-3}\ H$

$4A \longrightarrow -4A \qquad dt = 60\ ms$

$di = 4-(-4) = 8\ A$

$dt = 60 \times 10^{-3}\ s$

$e = L\dfrac{di}{dt}$ ✓ $\qquad e = N\dfrac{d\phi}{dt}$

$= 0.482 \times 10^{-3} \times \dfrac{8}{60 \times 10^{-3}}$

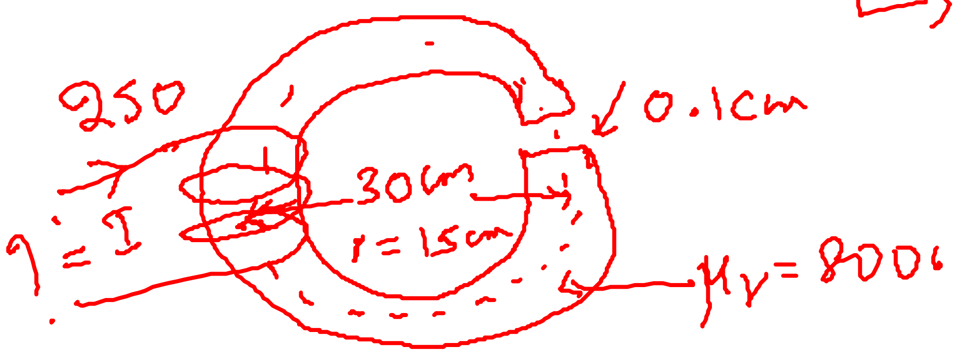
$= 0.0642\ V$

Simple problems

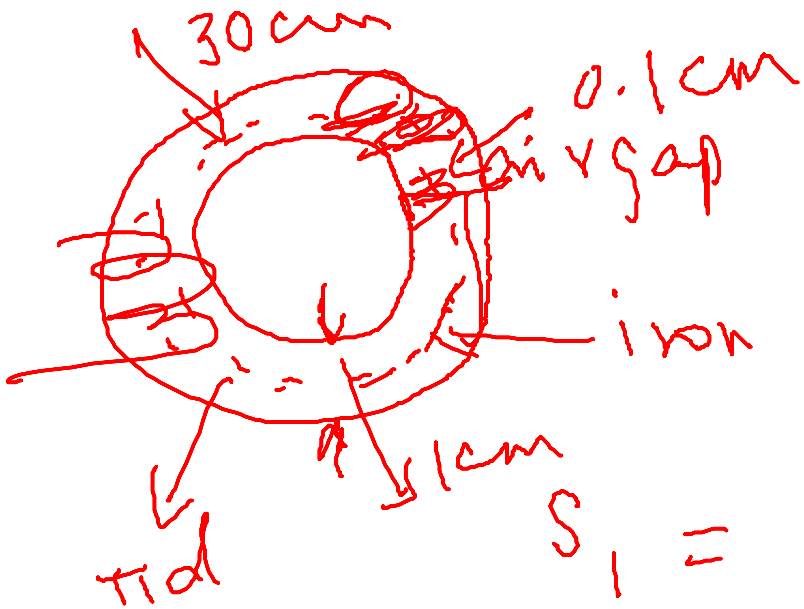
An iron rod of 1 cm radius is bent to a ring of mean diameter 30 cm and wound with 250 turns of wire. Assume the relative permeability of iron as 800. An airgap of 0.1 cm is cut across the bent ring. Calculate the current required to produce a useful flux of 20000 lines.

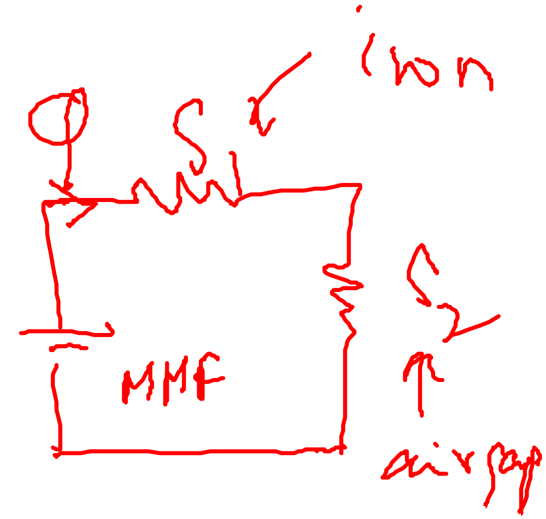
1cm

↳ 20000×10^{-8} Wb



Simple problems





$$S_1 = \frac{l_i}{\mu_0 \mu_r A}$$

$$S_2 = \frac{l_g}{\mu_0 \mu_r A}$$

$$l_g = 0.1\,cm = 0.001\,m$$

$$l_i = \pi d - 0.001$$

Simple problems

$$MMF = \overset{\checkmark}{N} \overset{\checkmark}{I}^{\,?}$$

$$MMF = S_1 \phi + S_2 \phi$$

$$250 \times I = \phi (S_1 + S_2)$$

$$I =$$

$$I = 4.41 A$$

Simple problems

Two inductively coupled coils have self-inductances $L_1 = 40$ mH and $L_2 = 150$ mH. If the coefficient of coupling is 0.7 (K)

(a) find the value of mutual inductance between the coils $M = K\sqrt{L_1 L_2}$

(b) the maximum possible mutual inductance. ?

$\boxed{K = 1}$

$M = \sqrt{L_1 L_2}$

Simple problems

Two coils connected in series have an equivalent inductance of 0.8 H when connected in aiding, and an equivalent inductance of 0.5 H when the connection is opposing. Calculate the mutual inductance of the coils.

$0.8 = L_{eq} = L_1 + L_2 + 2M$ aiding

$0.5 = L_{eq} = L_1 + L_2 - 2M$ opposing

$4M = 0.3$

$M = 0.3/4 =$

Simple problems

Using dot convention, write voltage equations for the coils 1 and 2.

$$v_1 = L_1\frac{di_1}{dt} + M\frac{di_2}{dt}$$

$$v_2 = L_2\frac{di_2}{dt} + M\frac{di_1}{dt}$$