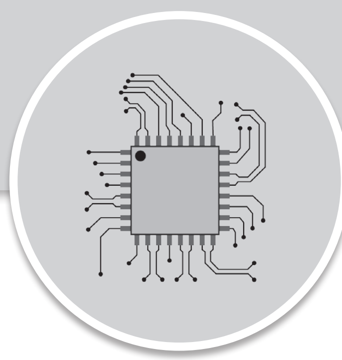
ELECTRONICS ENGINEERING

BASIC ELECTRICAL ENGINEERING



Comprehensive Theory
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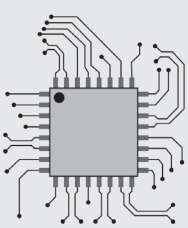
Basic Electrical Engineering



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1

Electromagnetism

1.1 ELECTRIC CURRENT

Electric current is defined as a stream of charged particles-such as electrons or ions-moving through an electrical conductor or space. It is the flow rate of electric charge through a conducting medium with respect to time.

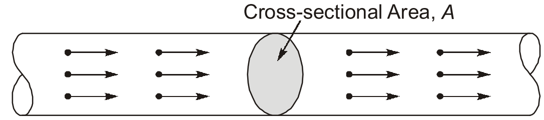
"Electric current may be defined as the time rate of net motion of electric charge across a cross-sectional area.".

The flow of current depends on the conductive medium. For example:

- In **conductor**, the flow of current is due to electrons.
- In **semiconductors**, the flow of current is due to electrons or holes.
- In an **electrolyte**, the flow of current is due to ions.
- In **plasma** – an ionized gas, the flow of current is due to ions and electrons.

i.e., electric current, i = Rate of transfer of electric charge

$$= \frac{\text{Quantity of electric charge transferred during a given time duration}}{\text{Time duration}} = \frac{dQ}{dt}$$



Coulomb is the practical as well as SI unit for measurement of electric charge. One coulomb is approximately equal to sum of 624×10^{16} electrons charge.

Since current is the rate of flow of electric charge through a conductor and coulomb is the unit of electric charge, the current may be specified in coulombs per second or Ampere.

Also, $$1e^- = 1.602 \times 10^{-19} \text{ C}$$

1.2 ELECTROMOTIVE FORCE AND POTENTIAL DIFFERENCE

1.2.1 Electromotive Force (EMF)

The characteristic of any energy source capable of pushing electric charge around a circuit is called electromotive force or EMF, which is the force inside a voltage source that drives current around a circuit. The electromotive force or EMF is the amount of energy provided by a cell to the unit charge. It is denoted by E.

1.2.2 Potential Difference (P.D)

When a Coulomb charge flows from one point to another, the potential difference, or voltage, is simply an indication of how much potential energy is gained or lost per coulomb. It's also known as the amount of work required to move potential energy per coulomb from one point to another. The energy released in the movement of a unit quantity of electricity from one place to the other is represented by the potential difference between two points in an electrical or electronic circuit. It is denoted by V.

NOTE: The important thing to understand is that EMF is the driving force, whereas the potential difference is the outcome of EMF.

In SI system of units, volt is the unit of electromotive force (EMF) and potential difference (P.D).

1.2.3 Difference Between EMF and Potential Difference

Both EMF and potential difference are measured in volts but there is a huge difference in their meaning. The main difference between EMF and potential difference is that the energy per unit charge exerted by an energy source is known as the EMF whereas the energy released when a unit quantity of electricity travels from one point to another is known as the potential difference. EMF or electromotive force is referred to as the terminal potential difference when no current flows.

Key Difference Between EMF and Potential Difference

EMF	Potential Difference
The quantity of energy delivered to each coulomb of charge is known as the electromotive force.	One coulomb of charge expends a certain amount of energy, which is called the potential difference.
The unit of EMF is Volt.	The unit of potential difference is Volt.
It is independent of resistance.	It depends upon resistance between two points.
It is measured using an emf meter.	It is measured using a voltmeter.
The electric, gravitational and magnetic fields are responsible for this.	The electric field is the sole source of potential difference.

1.3 RESISTANCE

Resistance may be defined as that property of a substance which opposes (or restricts) the flow of an electric current (or electrons) through it.

The SI unit of resistance is ohm (Ω), which is defined as resistance between two points of a conductor when a potential difference of one volt, applied between these points, produces in this conductor a current of one ampere, the conductor not being a source of any emf.

When an electric current flows through a bulb or any conductor, the conductor offers some obstruction to the current and this obstruction is known as electrical resistance and is denoted by R. Every material has an electrical resistance and this is the reason why conductors give out heat when current passes through it.

According to Ohm's law, there is a relation between the current flowing through a conductor and the potential difference across it. It is given by,

$$V \propto I \quad \Rightarrow V = IR$$

where, V is the potential difference measured across the conductor (in volts)
I is the current through the conductor (in amperes)
R is the constant of proportionality called resistance (in ohms)

Electric charge flows easily through some materials than others. The electrical resistance measures how much the flow of this electric charge is restricted within the circuit.

Resistance of a material: $R = \frac{\rho L}{A}$

Where, ρ = Resistivity of material

1.3.1 Factors Affecting Electrical Resistance

The electrical resistance of a conductor is dependent on the following factors:

- The cross-sectional area of the conductor. (A)
- Length of the conductor. (L)
- The material of the conductor. (ρ)
- The temperature of the conducting material.

Electrical resistance is directly proportional to length (L) of the conductor and inversely proportional to the cross-sectional area (A). It is given by the following relation.

1.4 OHM'S LAW

Ohm's law states that the voltage across a conductor is directly proportional to the current flowing through it, provided all physical conditions and temperature remain constant.

Mathematically, this current-voltage relationship is written as,

$$V = IR$$

In the equation, the constant of proportionality, R, is called Resistance and has units of ohms, with the symbol W.

The same formula can be rewritten in order to calculate the current and resistance respectively as follows:

$$I = \frac{V}{R} \quad \Rightarrow R = \frac{V}{I}$$

Ohm's law only holds true if the provided temperature and the other physical factors remain constant.

Ohm's law cannot be applied to circuits consisting of electronic tubes or transistors because such elements are not bilateral i.e., they behave in different way when the direction of flow of current is reversed as in case of a diode. Ohm's law also cannot be applied to circuits consisting of nonlinear elements such as powdered carbon, thyrite, electric arc etc. For example, for silicon carbide, the relationship between applied voltage (for potential difference) V and current flowing I is given as $V = K I^m$ where K and m are constants and m is less than unity.

1.4.1 Calculating Electrical Power Using Ohm's Law

The rate at which energy is converted from the electrical energy of the moving charges to some other form of energy like mechanical energy, heat energy, energy stored in magnetic fields or electric fields, is known as electric power. The unit of power is the watt. The electrical power can be calculated using Ohm's law and by substituting the values of voltage, current and resistance

Formula to find power

When the values for voltage and current are given,

$$P = VI$$

When the values for voltage and resistance are given,

$$P = \frac{V^2}{R}$$

When the values for current and resistance are given,

$$P = I^2R$$

1.4.2 Ohm's Law Applications

The main applications of Ohm's law are:

- To determine the voltage, resistance or current of an electric circuit.
- Ohm's law maintains the desired voltage drop across the electronic components.
- Ohm's law is also used in DC ammeter and other DC shunts to divert the current.

1.4.3 Limitations of Ohm's Law

Following are the limitations of Ohm's law.

- Ohm's law is not applicable for unilateral electrical elements like diodes and transistors as they allow the current to flow through in one direction only.
- For non-linear electrical elements with parameters like capacitance, resistance etc. the ratio of voltage and current won't be constant with respect to time making it difficult to use Ohm's law.

1.5 WORK, POWER AND ENERGY

Work : For a work to be done, a force must be exerted and there must be motion or displacement in the direction of the force. The work done by a force acting on an object is equal to the magnitude of the force multiplied by the distance moved in the direction of the force.

Work has only magnitude and no direction.

i.e., $$\text{Work done, } W = \text{Force } [\vec{F}] \cdot \text{distance } [\vec{d}] = Fd\cos\theta$$

From work equation, we can say that no work is done if:

- the displacement is zero.
- the force is zero.
- the force and displacement are mutually perpendicular to each other.

The SI or MKS unit of work is the joule, which is defined as the work done when a force of one newton acts through a distance of one metre in the direction of the force. Hence, if a force F acts through distance d in its own direction,

$$W = F\,[\text{newtons}] \times d\,[\text{metres}] = Fd \text{ joules}$$

Power : Power is defined as the rate of doing work or the amount of work done in unit time.

The MKS or SI unit of power is the joule/second or watt. In practice, the watt is often found to be inconveniently small and so a bigger unit, the kilowatt is frequently used.

$$1 \text{ kilowatt} = 1{,}000 \text{ watts}$$

Energy : Energy is the ability to perform work. Energy can neither be created nor be destroyed, and it can only be transformed from one form to another.

All forms of energy are either kinetic or potential energy. The energy in motion is known as kinetic energy, whereas potential energy is the energy stored in an object and is measured by the amount of work done.

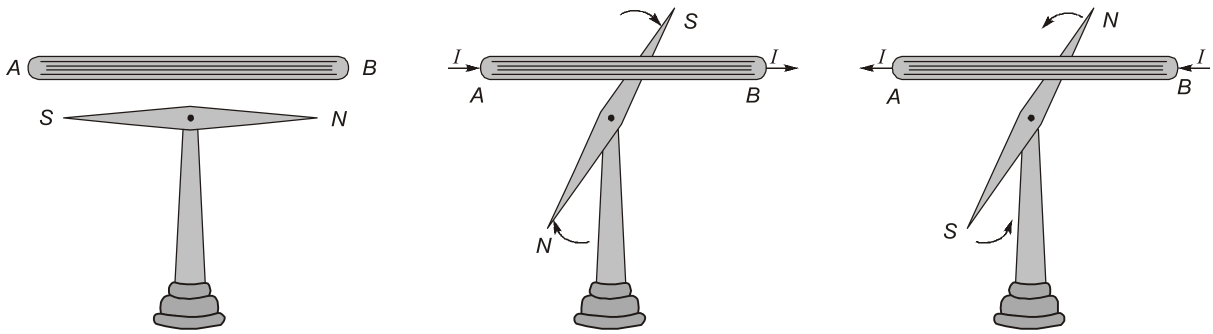
As already stated, in SI system the unit of energy of all forms is joule. Bigger unit of energy is mega joules (MJ) where 1 MJ = 10^6 J.

Calorie : It is the amount of heat required to raise the temperature of one gram of water through 1°C.

$$1 \text{ calorie} = 4.18 \text{ J} = 4.2 \text{ J}$$

1.6 MAGNETIC FIELD DUE TO A CURRENT CARRYING CONDUCTOR

In 1819, it was discovered by a Danish Physicist, Hans Christian Oersted that an electric current is always accomplished by certain magnetic effects.

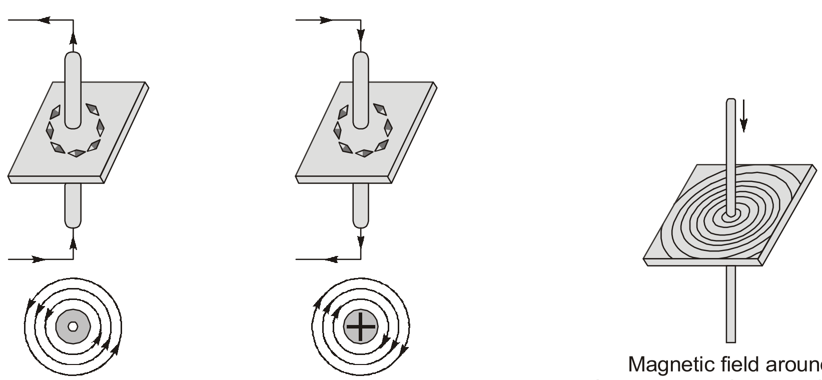


(a) No current flow **(b) Current flowing from *A* to *B*** **(c) Current flowing from *B* to *A***

Oersted found that when current is passed through a conductor placed above the magnetic needle, the needle turns in a certain direction, as shown in figures above. He also found that when the direction of flow of current is reversed the magnetic needle also deflects in opposite direction.

Further investigation showed that the field around the current carrying conductor consists of lines of force, which encircles the conductor. It can be proved experimentally by passing a current carrying conductor AB in the card board and plotting the field with the help of magnetic needle on it, as shown in figures below.

It is observed that when the current is passed through conductor in upward direction, the direction of lines of force is counterclockwise direction (observed from the top of the conductor) and when the current is passed through the conductor in downward direction, the direction of lines of force is clockwise (observed from the top of the conductor).



(d) **(e)** Magnetic field around A current carrying counductor

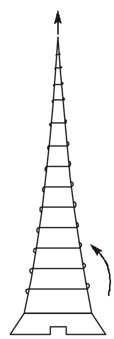
The properties of the lines of magnetic induction around a current carrying conductor are summarized as below:

(i) Lines of magnetic induction are circles, symmetrical about, and concentric with, the axis of the conductor.
(ii) The spacing between the lines of induction decreases as we move closer to the conductor.
(iii) The direction of lines of magnetic induction depends on the direction of flow of current through the conductor.
(iv) Magnetic induction or flux density depends upon the strength (or magnitude) of the current flowing through the conductor.

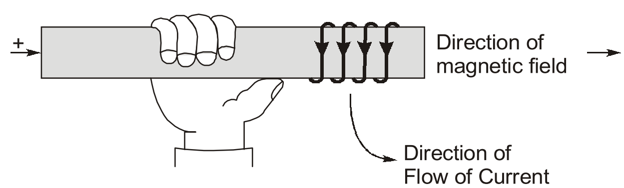
1.7 DETERMINATION OF DIRECTION OF MAGNETIC FIELD AROUND A CURRENT CARRYING CONDUCTOR

The direction of lines of force (magnetic field) around a straight current carrying conductor may be determined by any of the following rules :

1. **Corkscrew Rule :** If the right handed corkscrew is held with its axis parallel to the conductor pointing the direction of flow of current and the head of the screw is rotated in such a direction that the screw moves in the direction of flow of current then the direction in which the head of screw is rotated, will be the direction of magnetic lines of force.
2. **Right Hand Rule :** If the current carrying conductor is held in right hand by the observer so that it is encircled by fingers stretching the thumb at right angle to the fingers in the direction of flow of current then finger tips will point the direction of magnetic lines of force, as shown in figure (b).



(a) Corkscrew Rule



(b) Right hand rule

1.8 MAGNETIC FIELD DUE TO A CIRCULAR LOOP

If a single turn wire carrying current is bent in the form of a loop (or ring) as shown in figure. The lines of magnetic induction around it will be concentric circles, leaving the plane of the loop (or ring) on one side and entering on the other. The loop acts as the true magnet having north and south poles.

The direction of magnetic field may be determined by applying either of the two rules namely (i) right hand rule or (ii) corkscrew rule.

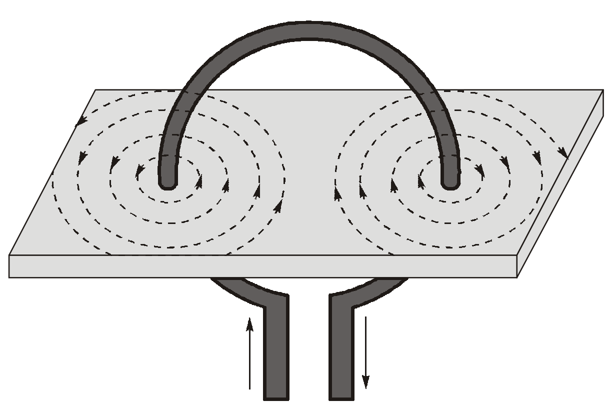
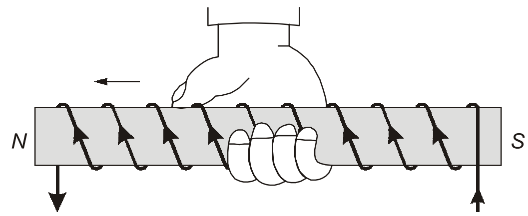


Fig.: Magnetic Field due to A Circular Loop

1.9 SOLENOID

The current carrying wire wound spirally in the form of helix about an axis, as shown in figure, is known as solenoid or coil. Magnetic field produced due to current carrying solenoid is fairly uniform over a small region in the middle of the coil. It acts just like a bar magnet having north and south poles.

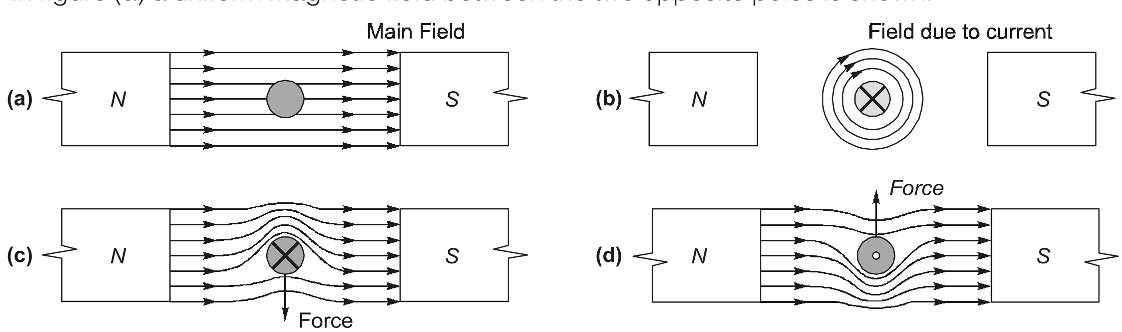
There are several methods used to determine the polarity of the solenoid.



1. **By Use of Compass Needle :** If one of the poles (say north pole) of the compass needle be brought into close proximity to one of the poles of the current carrying solenoid of unknown polarity the action of the compass needle will immediately classify the pole as north or south depending upon whether the needle is repelled or attracted.
2. **Helix Rule :** If the helix is held in right hand in such a manner that the finger tips point in the direction of flow of current and thumb is outstretched longitudinally along the coil, it will point towards north pole.

1.10 FORCE ON A CURRENT CARRYING CONDUCTOR LYING IN THE MAGNETIC FIELD

In figure (a) a uniform magnetic field between the two opposite poles is shown.



In figure (b) the cross section of a conductor carrying current in inward direction placed between the two magnets, the field being temporarily removed, is shown. By applying the right hand thumb rule, the direction of the field around the conductor is found to be clockwise.

If the current carrying conductor is placed in the magnetic field then, the resultant magnetic field would be similar to that shown in figure (c). The lines of force above the conductor are strengthened, since they are in same direction but the lines of force below the conductor are weakened because the two fields below the conductor are opposite in directions and hence tends to destroy each other. Magnetic lines like rubber bands have a tendency to strengthen out and, therefore, a force is experienced on the conductor in the downward direction, as shown in figure (c). If the direction of current is reversed in the conductor, as shown in figure (d), the direction of force experienced is reversed. In this case the lines of force above the conductor are weakened while those below the conductor are strengthened. Hence, it is observed that when a current carrying conductor is placed at right angle to the direction of magnetic field, a mechanical force is experienced on the conductor in a direction perpendicular to both the direction of magnetic field and flow of current.

The direction of this force can be determined by applying **Fleming's Left Hand Rule** which states that if the thumb, forefinger and middle finger of the left hand are stretched in such a way that they are at right angles to each other mutually and forefinger points towards the direction of the magnetic field, middle finger towards the direction of the flow of current then thumb will point the direction of force acting on the conductor as shown in figure.

Fleming's Left Hand Rule

If the current in the conductor is reversed, keeping the direction of magnetic field unchanged the direction of force will reverse. Similarly, if the direction of the magnetic field is reversed, keeping the direction of flow of current in the conductor unchanged, the direction of force will reverse.

Note: It should be noted that no force is exerted on a conductor when it lies parallel to the magnetic field.

The force experienced on the conductor is directly proportional to

1. Flux density (field strength), B
2. The current flowing through the conductor, I and
3. The length of the conductor, l

The magnitude of the force is given by, $F = BIl$

where F is the force in newtons, B is in tesla (Wb/m^2), I is in amperes and l is in metres.

In general, if the conductor lies at an angle θ with a magnetic field of flux density B weber/metre^2 then mechanical force experienced on a current carrying conductor is given by

$$F = BIl \sin\theta \qquad \text{Newtons}$$

where l is the length of the conductor in metres and I is the current carried by the conductor in ampere.

1.11 MAGNETICALLY INDUCED EMFS (OR VOLTAGES)

A very important effect of a magnetic field on an electric circuit is that when the flux linking the circuit changes, an emf is induced. Electromagnetic induction of emf (or voltage) is basic to the operation of transformers, generators (ac or dc) and motors (ac or dc). The effect is described by **Faraday's law**, which states that the magnitude of emf (or voltage) is directly proportional to the rate of change of flux linkage or to the product of number of turns and rate of change of flux linking the coil.

i.e., induced emf,
$$e = N\frac{d\phi}{dt}$$

where $N\frac{d\phi}{dt}$ is the product of number of turns and rate of change of linking flux and is termed as rate of change of flux linkage.

The direction of induced emf is governed by Lenz's law which states that the direction of induced emf or voltage is such that the current produced by it sets up a magnetic field opposing the flux change.

A minus (–) sign is required to be placed before the right hand side quantity of above equation just to indicate the phenomenon explained by Lenz's law. Thus the expression for induced emf becomes as

$$e = -N\frac{d\phi}{dt} \text{ volts}$$

where ϕ is in webers and time t is in second.

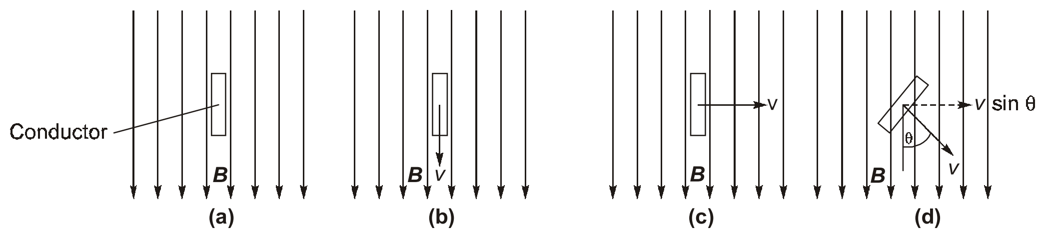
1.11.1 Dynamically Induced EMF

We have learn that when the flux linking with the coil or circuit changes, an emf is induced in the coil or circuit. EMF can be induced by changing the flux linking in two ways :

(i) By increasing or decreasing the magnitude of the current producing the linking flux. In this case there is no motion of the conductor or of coil relative to the field and, therefore, emf induced in this way is known as statically induced emf.

(ii) By moving a conductor in a uniform magnetic field and emf produced in this way is known as dynamically induced emf.

Consider a conductor of length l metres placed in a uniform magnetic field of density B Wb/m^2, as shown in figure (a).



Fleming's right hand rule

Let this conductor be moved with velocity (v) m/s in the direction of the field, as shown in figure (b). In this case no flux is cut by the conductor, therefore, no emf is induced in it.

Now if this conductor is moved with velocity (v) m/s in a direction perpendicular to its own length and perpendicular to the direction of the magnetic field, as shown in figure (c) flux is cut by the conductor, therefore, an emf is induced in the conductor.

Area swept per second by the conductor = $(l \times v)$ m^2/s

Flux cut per second = Flux density x area swept per second = B$l\,v$

Rate of change of flux, $\dfrac{d\phi}{dt}$ = Flux cut per second = Blv Wb/s

Induced emf, $e = \dfrac{d\phi}{dt} = Blv$ volts

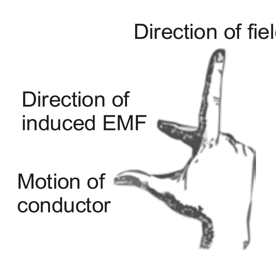
If the conductor is moved with velocity (v) m/s in a direction perpendicular to its own length and at an angle to the direction of magnetic field, as shown in figure (d).

The magnitude of emf induced is proportional to the component of the velocity in a direction perpendicular to the direction of the magnetic field and induced emf is given by

$$e = Blv\sin\theta \text{ volts}$$

The direction of this induced emf is given by Fleming's right hand rule.

If the thumb, forefinger and middle finger of right hand are held mutually perpendicular to each other, forefinger pointing into the direction of the field and thumb in the direction of motion of conductor then the middle finger will point in the direction of the induced emf as shown in figure below.



Fleming's right hand rule

1.11.2 Statically Induced EMF

Statically induced emf may be

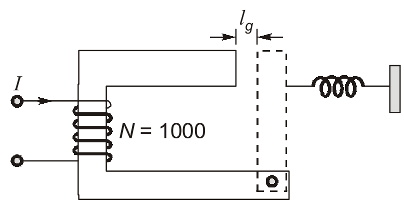
1. Self-induced emf   2. Mutually induced emf

1. Self Induced EMF : When the current flowing through the coil is changed, the flux linking with its own winding changes and due to the change in linking flux with the coil, an emf, known as self-induced emf, is induced.

EXAMPLE : 1.3 A relay (Given below) has a coil of 1000 turns and an air-gap of area 10 cm^2 and length 1.0 mm. Calculate the rate of change of stored energy in the air-gap of the relay when

(a) Armature is stationary at 1.0 mm from the core and current is 10 mA but is increasing at the rate of 25 A/s.

(b) Current is constant at 20 mA but inductance is changing at the rate of 100 H/s.



Solution:

$$L = \frac{\mu_0 N^2 A}{l_g} = \frac{4\pi\times 10^{-7}\times(10^3)^2\times 10\times 10^{-4}}{1\times 10^{-3}} = 1.26 \text{ H}$$

(i) Here, dI/dt = 25 A/s, dL/dt = 0 because armature is stationary.

$$\therefore \quad \frac{dE}{dt} = LI\frac{dI}{dt} = 1.26 \times 10 \times 10^{-3} \times 15 = 0.315 \text{ W}$$

(ii) Here, dL/dt = 100 H/s, dI/dt = 0 because current is constant

$$\therefore \quad \frac{dE}{dt} = \frac{1}{2}I^2\frac{dL}{dt} = \frac{1}{2}(20\times 10^{-3})^2\times 100 = 0.02 \text{ W}$$

OBJECTIVE BRAIN TEASERS

Q.1 **Assertion (A) :** In an electric circuit, the current is due to the presence of electromotive force.
Reason (R) : In a magnetic circuit, the magnetic flux is due to the presence of a magnetomotive force.
(a) Both A and R are true and R is a correct explanation of A.
(b) Both A and R are true but R is not a correct explanation of A.
(c) A is true but R is false.
(d) A is false but R is true.

Q.2 **Assertion (A):** Leakage flux has a path dominated through the surrounding air.
Reason (R): Leakage flux may be defined as that flux which does not follow the intended path in a magnetic circuit.
(a) Both A and R are true and R is the correct explanation of A
(b) Both A and R are true but R is not the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

Q.3 A conductor 20 cm long moves at right angle to its length at a constant speed of 30 m/s in a uniform magnetic field of flux density 1.2 T. The emf induced in case the conductor motion is normal to the field flux is
(a) 0 volt (b) 28.8 volt
(c) 7.2 volt (d) 14.4 volt

Q.4 A magnetic circuit with relative permeability of 100 has a core cross-sectional area of 5 cm^2 and mean core length of 25 cm. The coil has 120 turns with an mmf of 1000 AT. The magnetic core flux is
(a) 0.75 mWb (b) 1 mWb
(c) 0.05 mWb (d) 0.25 mWb

Q.5 Building steel core out of stampings reduces eddy current loss because,

(a) it increases core resistivity.

(b) it increases the effective length of eddy current paths thereby increasing effective resistance to the flow of eddy currents.

(c) it increases core permeability.

(d) it reduces the effective length of eddy current path, thereby reducing effective resistance to the flow of eddy currents.

Q.6 In a 4-pole dynamo, the flux/pole is 15 mWb. The average emf induced in one of the armature conductors, if armature is driven at 600 rpm

(a) 2.5 V (b) 0.6 V

(c) 9 V (d) 0.9 V

Q.7 Match **List-I (Electric Circuit)** with **List-II (Magnetic Circuit)** and select the correct answer using the codes given below the lists:

List-I	List-II
A. Current	1. Magnetic flux density
B. Conductivity	2. Magnetic field intensity
C. Electric field intensity	3. Magnetic flux
D. Current density	4. Permeability

Codes:

	A	B	C	D
(a)	2	4	3	1
(b)	3	4	2	1
(c)	2	3	4	1
(d)	3	1	2	4

Q.8 One 800-turn flat coil with an area of 5×10^{-2} m^2 is rotating in a magnetic field of flux density 60 mWb/m^2 at 1500 rpm. The value of induced emf in the coil if the plane of the coil is parallel to the field is

(a) 375 V (b) 288 V

(c) 392 V (d) 377 V

Q.9 A cast steel electromagnet has an airgap of length 2 mm and an iron path of length 30 cm. The number of ampere turns necessary to produce a flux density of 0.8 Wb/m^2 in the gap is _____. Neglect leakage and fringing. (For 0.8 Wb/m^2 cast steel requires 750 AT/m).

Q.10 A cast steel ring has a circular cross-section 3 cm in diameter and a mean circumference of 80 cm. The ring is uniformly wound with 600 turns.

(a) The current required to produce a flux of 0.5 m Wb in the ring is _____ A.

(b) If a saw cut 2 mm wide is made in the ring, then approximately the flux produced by the current found in (a) is _____ mWb.

(c) The current value which will give the same flux as in (a), after the air gap of 2 mm is made in the ring is _____ A.

Assume the gap density to be the same as in the iron and neglect fringing.

(For 0.705 Wb/m^2 cast steel requires 670 AT/m).

Q.11 An iron ring of mean length 50 cm has an air gap of 1 mm and a winding of 200 turns. If the permeability of the iron is 300 and a current of 1 A flows through the coil, then the flux density is _____.

Q.12 Why the transformer stampings are varnished before being used to build the core?

(a) To increase air-gap between stampings

(b) To reduce hysteresis loss

(c) To reduce eddy current loss

(d) To provide strength to the core

Q.13 Maximum flux established in an AC excited iron core is influenced by

(a) frequency only

(b) voltage only

(c) both voltage and frequency

(d) reluctance of the core

Q.14 A circular iron core has an air-gap cut in it and is excited by passing direct current through a coil wound on it. The magnetic energy stored in the air-gap and the iron core is

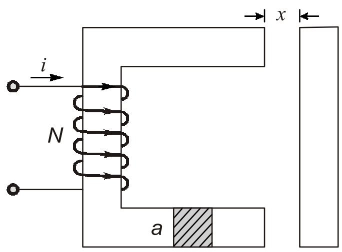
(a) in inverse ratio of their reluctance

(b) in direct ratio of their reluctances

(c) equally divided among then

(d) energy resides wholly in the iron core

Q.15 In the electromagnetic relay of given figure below the reluctance of the iron path is negligible. The coil self-inductance is given by the expression



(a) $\mu_0 N^2 a/x$ (b) $\mu_0 N/2\,ax$
(c) $\mu_0 N^2 a/2x$ (d) $\mu_0 N^2/2\,ax$

Q.16 An iron-cored choke with 1 mm air-gap length, draws 1 A when fed from a constant voltage AC source of 220 V. If the length of air-gap is increased to 2 mm, the current drawn by the choke would

(a) become nearly one half
(b) remain nearly the same
(c) become nearly double
(d) become nearly zero

ANSWERS KEY

1. (b)	**2.** (a)	**3.** (c)	**4.** (d)	**5.** (b)
6. (b)	**7.** (b)	**8.** (d)	**9.** (1498.24)	
10. (Sol)	**11.** (Sol)	**12.** (c)	**13.** (c)	**14.** (b)
15. (c)	**16.** (c)			

HINTS & EXPLANATIONS

1. (b)

$$I = \frac{\text{EMF}}{R} \text{ (for an electric circuit)}$$

$$\phi = \frac{\text{MMF}}{\text{Reluctance}}$$

(for a magnetic circuit)

3. (c)

Given, $\theta = 90°$

$\therefore$ emf induced $= B\,l\,v\sin\theta$

$= 1.2 \times 0.2 \times 30 \times \sin 90°$

$= 7.2$ volt

4. (d)

Given, $\mu_r = 100$, $a = 5$ cm^2, $l = 25$ cm, $N = 120$ turns, $NI = \text{MMF} = 1000$ AT

We know that,

$$\text{Flux} = \frac{\text{MMF}}{\text{Reluctance}}$$

$$= \frac{NI}{\left(\dfrac{l}{\mu_0\mu_r A}\right)} = \frac{NI \cdot \mu_0\,\mu_r A}{l}$$

$$\text{or, Flux} = \frac{1000 \times 4\pi \times 10^{-7} \times 100 \times 5 \times 10^{-4}}{25 \times 10^{-2}}$$

$$= \frac{4\pi}{5} \times 10^{-4} = 0.25 \text{ mWb}$$

5. (b)

Building steel core out of stampings increases the path of eddy currents, which leads to the increase in effective resistance, thereby reducing eddy current losses.

6. (b)

It should be noted that each time the conductor passes under a pole, it cuts a flux of 15 mWb. Hence, the flux cut in one revolution is $15 \times 4 = 60$ mWb. Since conductor is rotating at $\frac{600}{60} = 10$ rps.

Time taken for one revolution is

$$\frac{1}{10} = 0.1 \text{ sec}$$

$$\therefore \quad \text{emf} = \frac{Nd\phi}{dt}$$

$$d\phi = 6 \times 10^{-2} \text{ Wb}$$

$$dt = 0.1 \text{ sec}$$

$$e = \frac{1 \times 6 \times 10^{-2}}{0.1} = 0.6 \text{ V}$$

$\therefore$ The total flux $= \dfrac{\text{Total AT}}{\text{Relutance}} = \dfrac{200 \times 1 \times 3\, A\mu_0}{8 \times 10^{-3}}$

$\therefore$ The flux density

$$= \frac{600 \times \mu_0}{8 \times 10^{-3}} \text{ Wb/m}^2$$

$$= \frac{600 \times 4\pi \times 10^{-7}}{8 \times 10^{-3}}$$

$$= 94.2 \text{ mWb/m}^2$$

12. (c)

In order to reduce the eddy current losses, laminations made in the core are insulated from one-another by thin layers of varnish.

13. (c)

$$\phi \propto \frac{V}{f}, \text{ i.e., flux} \propto \frac{\text{Voltage}}{\text{Frequency}}$$

14. (b)

$\because \quad W = \dfrac{1}{2}\phi^2 S$

$\therefore \quad W \propto S$ (Reluctance)

15. (c)

$$\phi = \frac{NI}{S} = \frac{Ni}{\dfrac{2x}{\mu_o a}}$$

$$= \frac{Ni\mu_o a}{2x}$$

$\because \quad N\phi = Li$

$\therefore \quad L = \dfrac{N\phi}{i} = \dfrac{N^2\mu_o a}{2x}$

16. (c)

$$\phi = \frac{NI\mu_o A}{l}$$

(ignoring reluctance of iron)

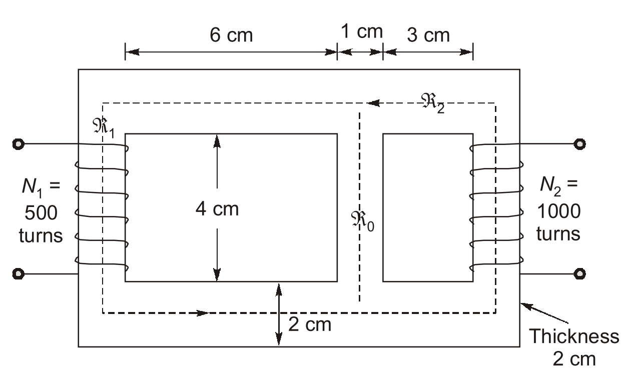
$$I = \frac{l\phi}{N\mu_o A}$$

$I \propto l$

$I' = 2I$ for $l' = 2l$

CONVENTIONAL BRAIN TEASERS

Q.1 For the magnetic circuit of figure find the self and mutual inductances between the two coils. Core permeability = 1600.



1. (Sol)

$l_1 = (6 + 0.5 + 1) \times 2 + (4 + 2) = 21$ cm

$l_2 = (3 + 0.5 + 1) \times 2 + (4 + 2) = 15$ cm

$l_0 = 4 + 2 = 6$ cm