ELECTROMAGNETISM

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Magnetic Effect of Electric Current

Magnetic Effect of Electric Current – A magnetic field is a force field that is created by magnetic dipoles and moving electric charges, and it exerts a force on other nearby moving charges and magnetic dipoles. Magnetic Field is a vector quantity because it has both magnitude and direction.

Magnetic Field Lines

A magnetic field line or lines of forces shows the strength of a magnet and the direction of a magnet's force. It was discovered by Michael Faraday to visualize the magnetic field.

Direction of Field Lines

Magnetic field lines are directed from south pole to north pole inside the magnet and from north pole to south pole outside the magnet.

Strength of Magnetic Field Lines

A straight current-carrying conductor has a magnetic field in the shape of concentric circles around it. The magnetic field of a straight current-carrying conductor can be visualized by magnetic field lines.

The direction of a magnetic field produced due to a current-carrying conductor rely upon the same direction in which the current is flowing

The direction of the electric field gets reversed if the direction of electric current changes.

Oersted Experiment

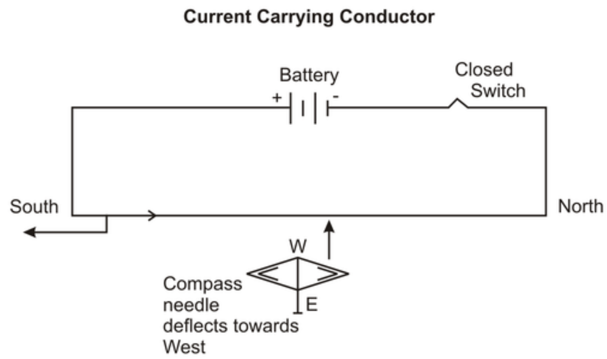
In 1820, Oersted established the relationship between electricity and magnetism. He concluded that a current carrying wire produces a magnetic field around it.

Aim:

To show that a current carrying wire produces a magnetic field around it.

Experiment Setup:

A thick insulated copper wire is taken and connected with the battery in such a way that current flows from South to North direction in the wire. A compass needle is placed under the wire.



Observations:

1. When electric current is passed through the wire from South (S) to North (N) directions and the wire is placed over (O) the compass needle, the compass needle gets deflected towards West (W) direction (SNOW Rule).

2. On reversing the direction of current in the wire, the compass needle gets deflected in the opposite direction.

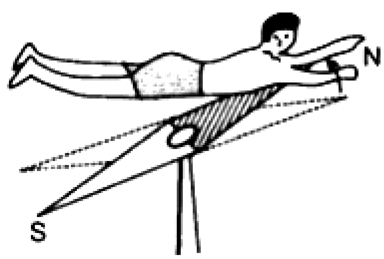
3. When current is switched off, then there is no deflection in the compass needle.

Conclusion:

The deflection of compass needle, whenever there is current in the wire shows that a current carrying wire produces a magnetic field around it.

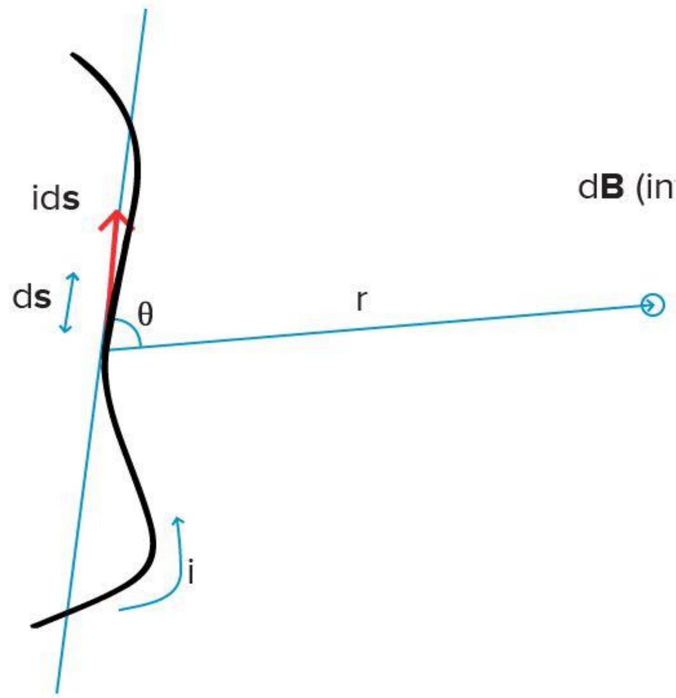
What is ampere swimming rule?

Ampere's swimming rule states that, "If a man swims along the wire carrying current such that his face is always towards the magnetic needle with current entering his feet and leaving his head, then the north pole of the magnetic needle is always deflected towards his left hand."



What is Biot-Savart Law?

Biot-Savart's law is an equation that gives the magnetic field produced due to a current carrying segment. This segment is taken as a vector quantity known as the current element.



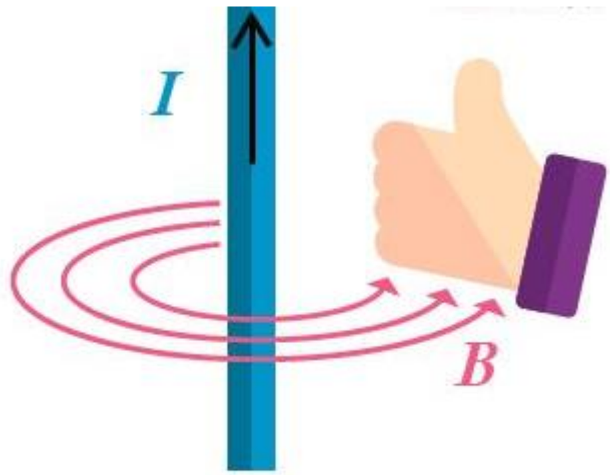
Consider a current carrying wire 'i' in a specific direction as shown in the above figure. Take a small element of the wire of length ds. The direction of this element is along that of the current so that it forms a vector i ds.

To know the magnetic field produced at a point due to this small element, one can apply Biot-Savart's Law. Let the position vector of the point in question drawn from the current element be **r** and the angle between the two be θ. Then,

$$|dB|=(\mu_0/4\pi)(I\times dl\times \sin\theta/r^2)$$

Where, μ_0 is the permeability of free space and is equal to $4\pi \times 10^{-7}$ TmA^{-1}.

The direction of the magnetic field is always in a plane perpendicular to the line of element and position vector. It is given by the **right-hand thumb rule** where the thumb points to the direction of conventional current and the other fingers show the magnetic field's direction.



Applications of Biot-Savart's Law:

- We can use Biot–Savart law to calculate magnetic responses even at the atomic or molecular level.
- It is also used in aerodynamic theory to calculate the velocity induced by vortex lines.

Importance of Biot-Savart Law

- Biot-Savart law is similar to the Coulomb's law in electrostatics.
- The law is applicable for very small conductors too which carry current.
- The law is applicable for symmetrical current distribution.

Q. A circular coil of radius 5×10^{-2} m and with 40 turns is carrying a current of 0.25 A. Determine the magnetic field of the circular coil at the center.

Ans: The radius of the circular coil = 5×10^{-2} m

Number of turns of the circular coil = 40

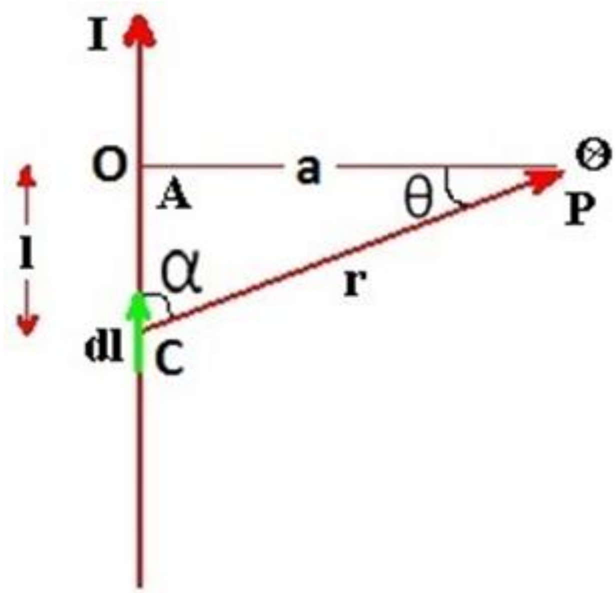
Current carried by the circular coil = 0.25 A

Magnetic field is given as:

B=μ0NI/2a

= 4π×10−7T.m/A(40)0.25A/2.50×10−2m
= 1.2×10^{-4} T

MAGNETIC FIELD DUE TO A STRAIGHT CURRENT CARRYING CONDUCTOR:



Consider an infinitely long conductor AB through which current I flows. Let P be any point at a distance a from the centre of conductor. Consider dl be the small current carrying element at point c at a distance r from point p. α be the angle between r and dl. l be the distance between centre of the coil and elementary length dl.
From biot-savart law, magnetic field due to current carrying element dl at point P is

$$dB = \frac{\mu_\circ}{4\pi}\frac{Idlsin\alpha}{r^2} - - - - - - - - - -(i)$$

$$from\ fig, sin\alpha = \frac{a}{r} = cos\theta$$

$$r = \frac{a}{cos\theta} - - - - - -(ii)$$

$$again, tan\theta = \frac{a}{l}$$

$$dl = a\sec^2\theta d\theta - - - - - - -(iii)$$

from above three equations

$$dB = \frac{\mu_\circ}{4\pi} \frac{Ia \sec^2 \theta d\theta \ \ cos\theta}{(\frac{a}{cos\theta})^2}$$

$$dB = \frac{\mu_\circ}{4\pi} \frac{Ia \sec^2 \theta d\theta \ \ cos\theta}{(a)^2} \cos^2 \theta$$

$$dB = \frac{\mu_\circ}{4\pi} \frac{Icos\theta d\theta}{a}$$

Total magnetic field due to straight current carrying conductor is

$$B = \int_{-\theta_1}^{\theta_2} \frac{\mu_\circ}{4\pi} \frac{Icos\theta d\theta}{a}$$

$$B = \frac{\mu_\circ}{4\pi} \frac{I}{a} \int_{-\theta_1}^{\theta_2} cos\theta d\theta$$

$$B = \frac{\mu_\circ}{4\pi} \frac{I}{a} [sin\theta] \begin{matrix} \theta_2 \\ -\theta_1 \end{matrix}$$

$$B = \frac{\mu_\circ}{4\pi} \frac{I}{a} (sin\theta_2 + sin\theta_1)$$

This is the final expression for total magnetic field due to straight current carrying conductor.

If the conductor having infinite length then,

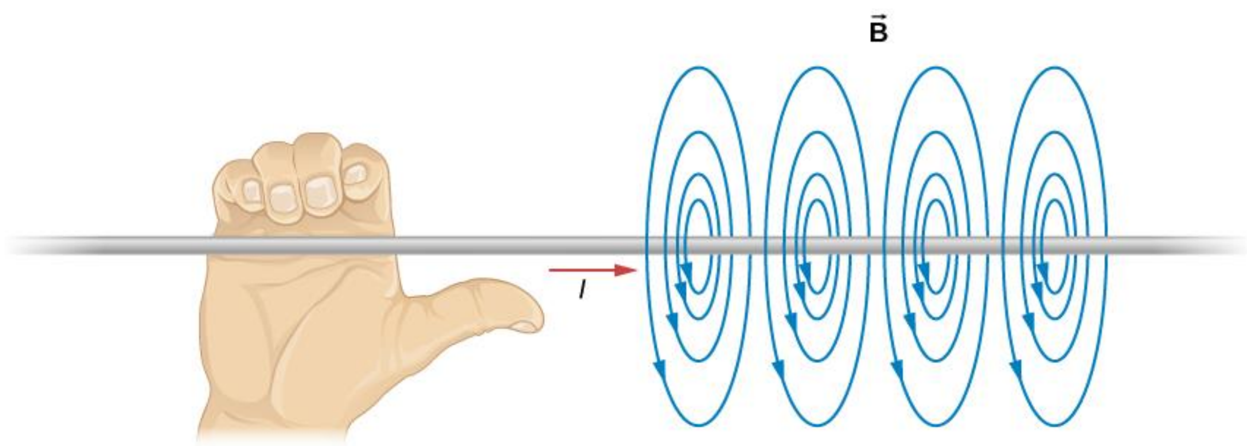
$$\theta_1 = \theta_2 = \frac{\pi}{2}$$

$$B = \frac{\mu_\circ}{4\pi}\frac{I}{a}\left(\sin\frac{\pi}{2} + \sin\frac{\pi}{2}\right)$$

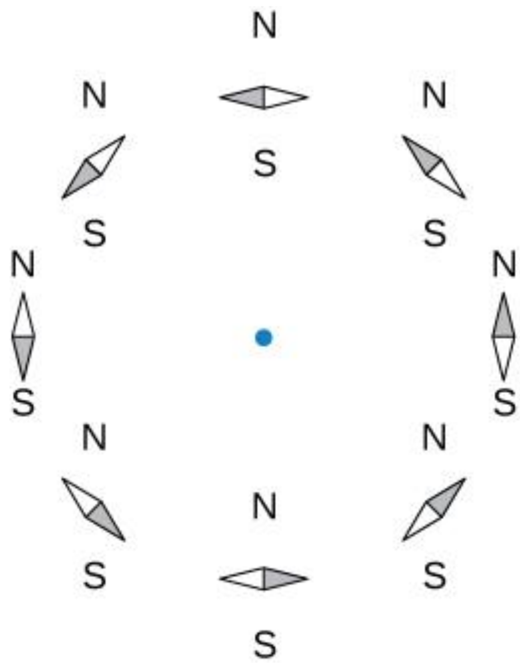
$$B = \frac{\mu_\circ}{4\pi}\frac{I}{a}2$$

$$B = \frac{\mu_\circ}{2\pi}\frac{I}{a} \quad Tesla$$

The direction of this magnetic field may be found with a second form of the **right-hand rule**. If you hold the wire with your right hand so that your thumb points along the current, then your fingers wrap around the wire in the same sense as $\vec{B}$ B→.



The direction of the field lines can be observed experimentally by placing several small compass needles on a circle near the wire. When there is no current in the wire, the needles align with Earth's magnetic field. However, when a large current is sent through the wire, the compass needles all point tangent to the circle. Iron filings sprinkled on a horizontal surface also delineate the field lines, as shown in Figure

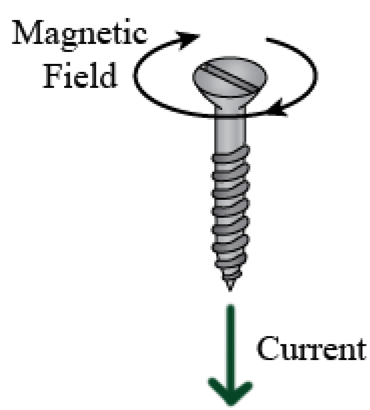


(a)

(b)

Right Handed Cork Screw Rule

If a right handed cork screw is assumed to be held along the conductor, and the screw is rotated such that it moves in the direction of the current, direction of magnetic field is same as that of the rotation of the screw.



Magnetic field along the Centre of circular current carrying coil

Consider a circular current carrying coil having radius r and centre O. When the current is passing through the circular coil, magnetic field is produced. To find the magnetic field at the centre of the circular coil, consider a length of element dl at point p which is tangent to the circular coil. The angle between element dl and radius r is 90°.
According to the biot-savart law, the magnetic field at the centre of the circular coil due to

$$dB = \frac{\mu_\circ}{4\pi}\frac{Idlsin\theta}{r^2} = \frac{\mu_\circ}{4\pi}\frac{Idlsin90}{r^2} = \frac{\mu_\circ}{4\pi}\frac{Idl}{r^2}$$

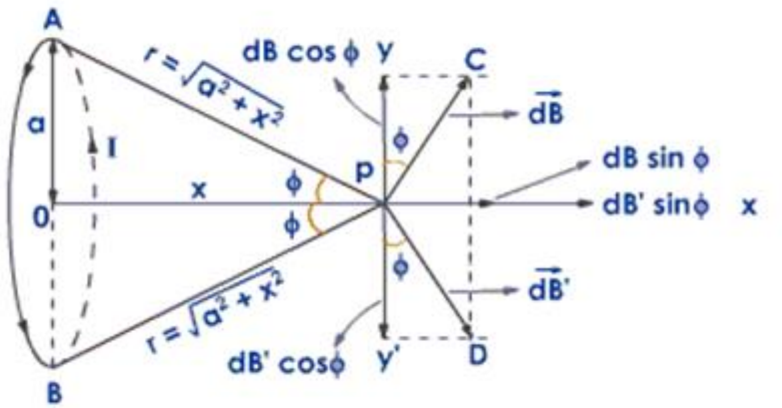
Total magnetic field due to the circular coil is

$$B = \int_0^{2\pi r} dB = \int_0^{2\pi r} \frac{\mu_\circ}{4\pi}\frac{Idl}{r^2} = \frac{\mu_\circ}{4\pi}\frac{I}{r^2}\int_0^{2\pi r} dl$$
$$= \frac{\mu_\circ}{4\pi}\frac{I}{r^2}[l]\begin{matrix}2\pi r\\0\end{matrix}$$
$$= \frac{\mu_\circ}{4\pi}\frac{I}{r^2}2\pi r$$
$$= \frac{\mu_\circ}{2}\frac{I}{r}$$

If there are n number of circular coil then their magnetic field is :

$$B = \frac{\mu_\circ}{2}\frac{nI}{r}$$

Magnetic field at the axis of the circular current carrying coil :



Consider a circular coil having radius a and centre O from which current I flows in anticlockwise direction. The coil is placed at YZ plane so that the centre of the coil coincide along X-axis. P be the any point at a distance x from the centre of the coil where we have to calculate the magnetic field. let dl be the small current carrying element at any point A at a distance r from the point P

where $r = \sqrt{r^2 + a^2}$

the angle between r and dl is 90°. Then fron biot-savart law, the magnetic field due to current carrying element dl is

$$dB = \frac{\mu_\circ}{4\pi}\frac{Idlsin\theta}{r^2} = \frac{\mu_\circ}{4\pi}\frac{Idlsin90}{r^2} = \frac{\mu_\circ}{4\pi}\frac{Idl}{r^2}$$

the direction of magnetic field is perpendicular to the plane containing dl and r. So the magnetic field dB has two components

$$dBcos\theta \; is \; along \; the \; Y - axis$$
$$dBsin\theta \; is \; along \; the \; X - axis$$

Similarly, consider another current carrying element dl’ which is diametrically opposite to the point A. The magnetic field due to this current carrying element dB’ also has two components

$$dB'cos\theta\ is\ along\ the\ Y - axis$$
$$dB'sin\theta\ is\ along\ the\ X - axis$$

Here both dBcosθ and dB’cosθ are equal in magnitude and opposite in direction. So they cancle each other. Similarly, the components dBsinθ and dB’sinθ are equal in magnitude and in same direction so they adds up.

Total magnetic field due to the circular current carrying coil at the axis is

$$B = \int_0^{2\pi a} dB sin\theta = \int_0^{2\pi a} \frac{\mu_\circ}{4\pi} \frac{Idl}{r^2} \frac{a}{r}$$

$$since\ sin\theta = \frac{a}{r} B = \int_0^{2\pi a} \frac{\mu_\circ}{4\pi} \frac{Idl}{(x^2 + a^2)} \frac{a}{(x^2 + a^2)^{\frac{1}{2}}} = \frac{\mu_\circ}{4\pi} \frac{Ia}{(x^2 + a^2)^{\frac{3}{2}}} \int_0^{2\pi a} dl$$

$$B = \frac{\mu_\circ}{4\pi} \frac{Ia}{(x^2 + a^2)^{\frac{3}{2}}} 2\pi a$$

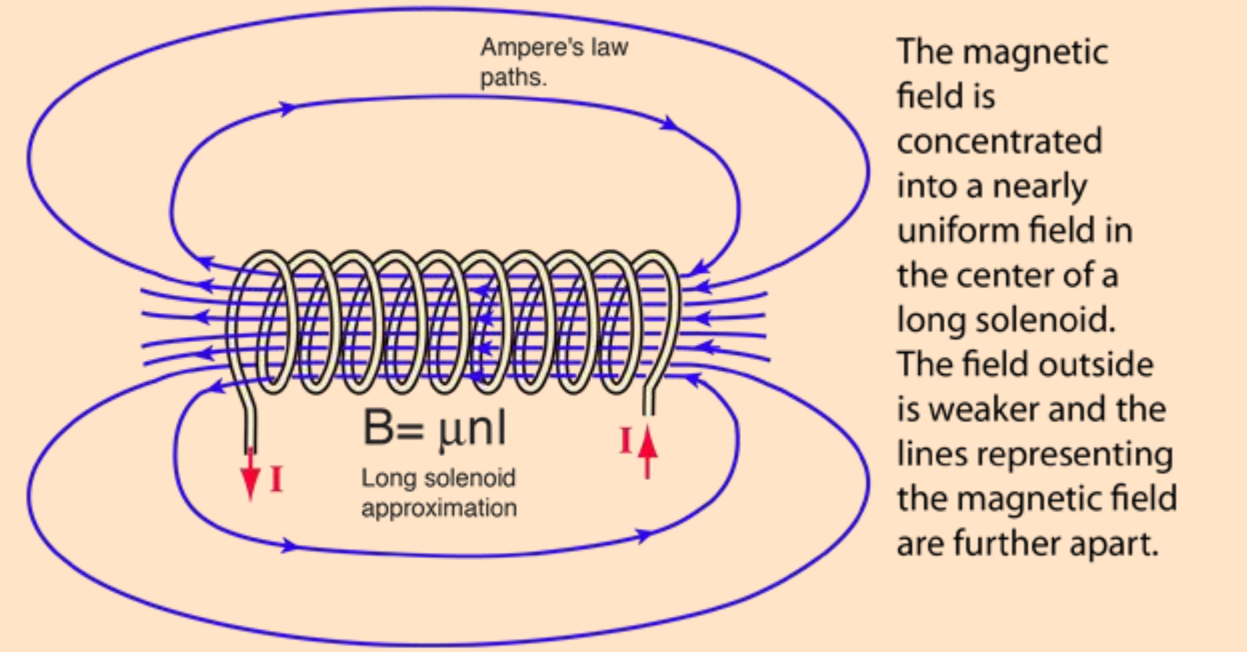
$$B = \frac{\mu_\circ}{2} \frac{Ia^2}{(x^2 + a^2)^{\frac{3}{2}}}\ Tesla$$

This is the expression for magnetic field due to circular current carrying coil along its axis. If the coil having N number of turns then magnetic field along its axis is

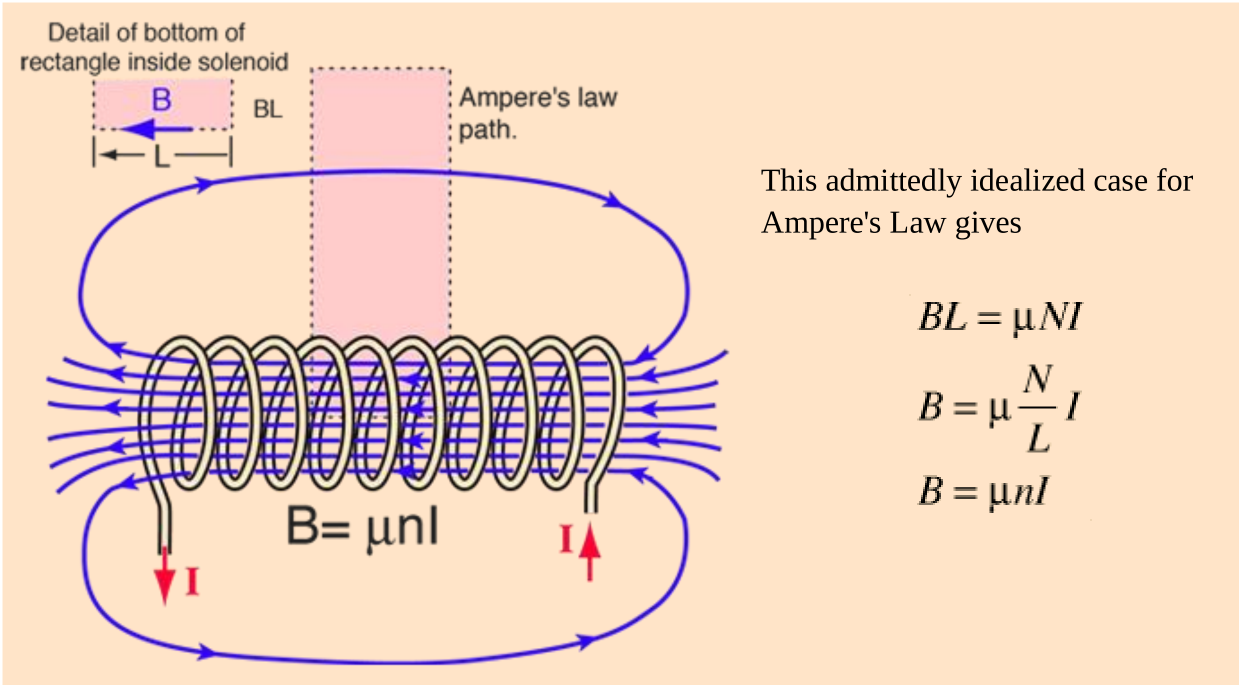
$$B = \frac{\mu_\circ}{2} \frac{INa^2}{(x^2 + a^2)^{\frac{3}{2}}}\ Tesla$$

SOLENOID

A long straight coil of wire can be used to generate a nearly uniform magnetic field similar to that of a bar magnet. Such coils, called solenoids, have an enormous number of practical applications. The field can be greatly strengthened by the addition of an iron core. Such cores are typical in electromagnets.

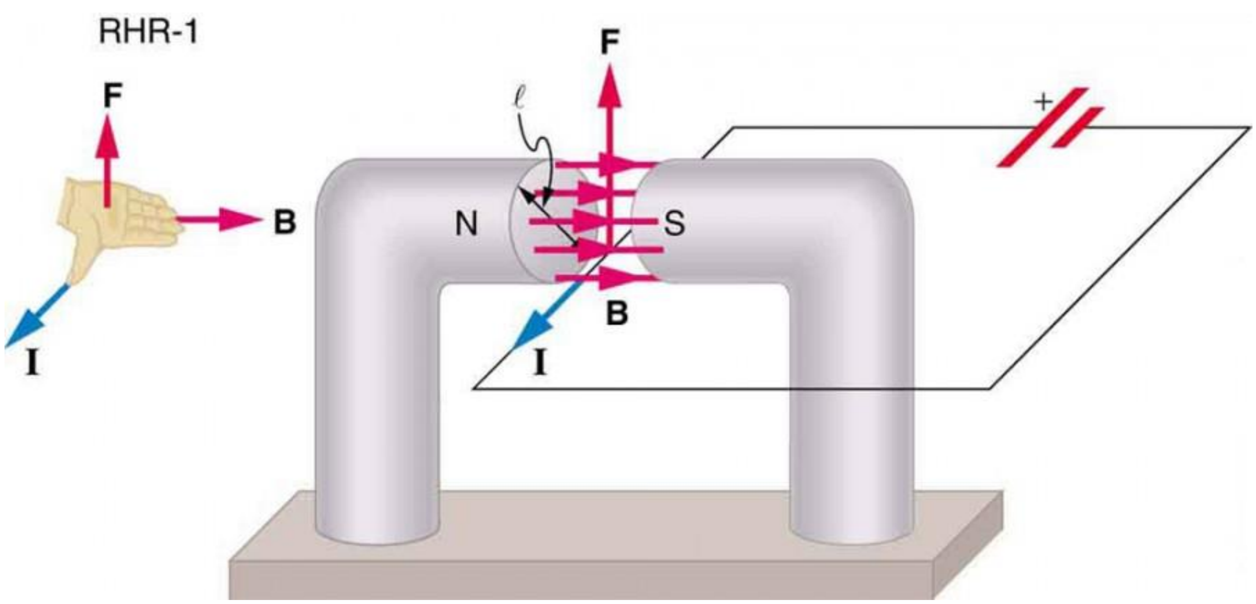


Taking a rectangular path about which to evaluate Ampere's Law such that the length of the side parallel to the solenoid field is **L** gives a contribution **BL** inside the coil. The field is essentially perpendicular to the sides of the path, giving negligible contribution. If the end is taken so far from the coil that the field is negligible, then the length inside the coil is the dominant contribution.



Magnetic Force on a Current-Carrying Conductor

Because charges ordinarily cannot escape a conductor, the magnetic force on charges moving in a conductor is transmitted to the conductor itself.



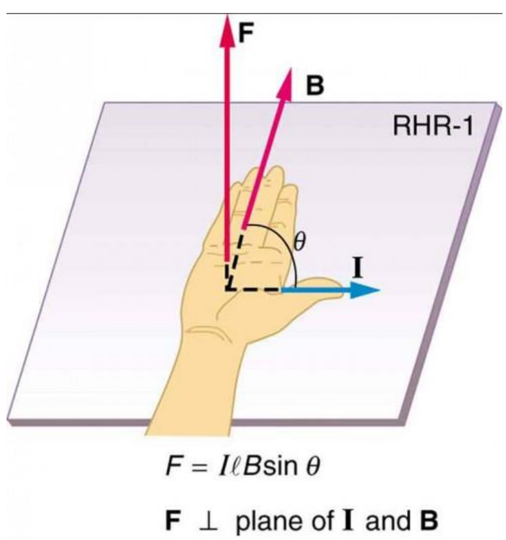
We can derive an expression for the magnetic force on a current by taking a sum of the magnetic forces on individual charges. (The forces add because they are in the same direction.) The force on an individual charge moving at the drift velocity v_d is given by $F = qv_dB \sin \theta$. Taking B to be uniform over a length of wire l and zero elsewhere, the total magnetic force on the wire is then F = (qv_dB sin θ)(N), where N is the number of charge carriers in the section of wire of length l. Now, $N = nV$, where n is the number of charge carriers per unit volume and V is the volume of wire in the field. Noting that $V = Al$, where A is the cross-sectional area of the wire, then the force on the wire is F = (qv_dB sin θ) (nAl). Gathering terms,

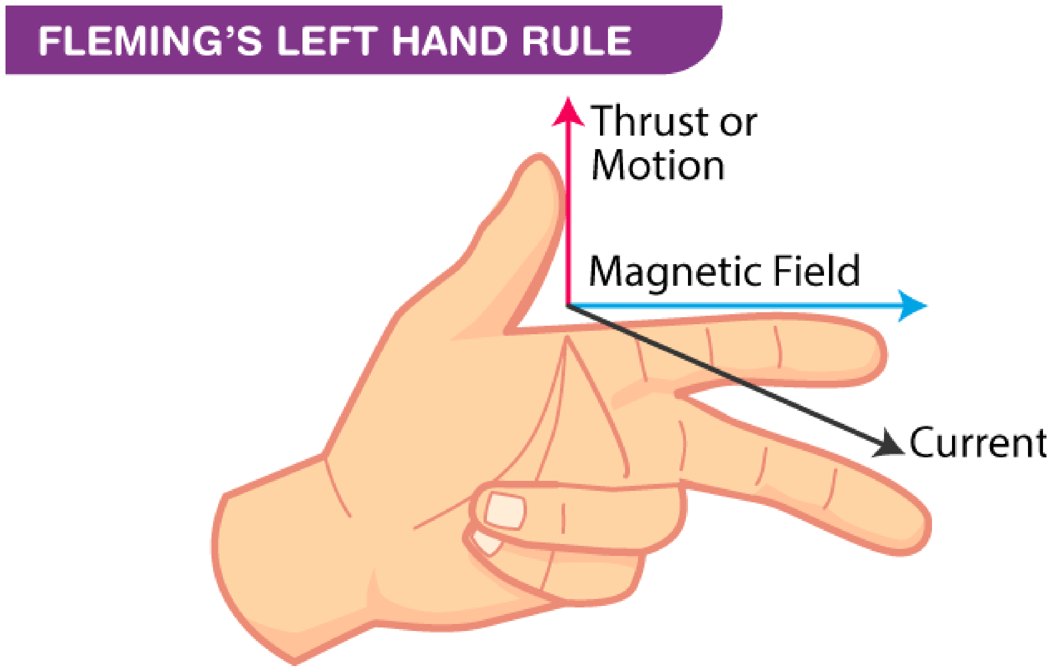
$$F=(nqAv_d)lB\sin\theta \quad F=(nqAv_d)lB\sin\theta.$$

Because $nqAv_d = I$

$$F=IlB\sin\theta$$

is the equation for *magnetic force on a length l of wire carrying a current I in a uniform magnetic field B*. If we divide both sides of this expression by l, we find that the magnetic force per unit length of wire in a uniform field is $F/l=IB\sin\theta$. The direction of this force is given by Right hand rule, with the thumb in the direction of the current I. Then, with the fingers in the direction of B, a perpendicular to the palm points in the direction of F



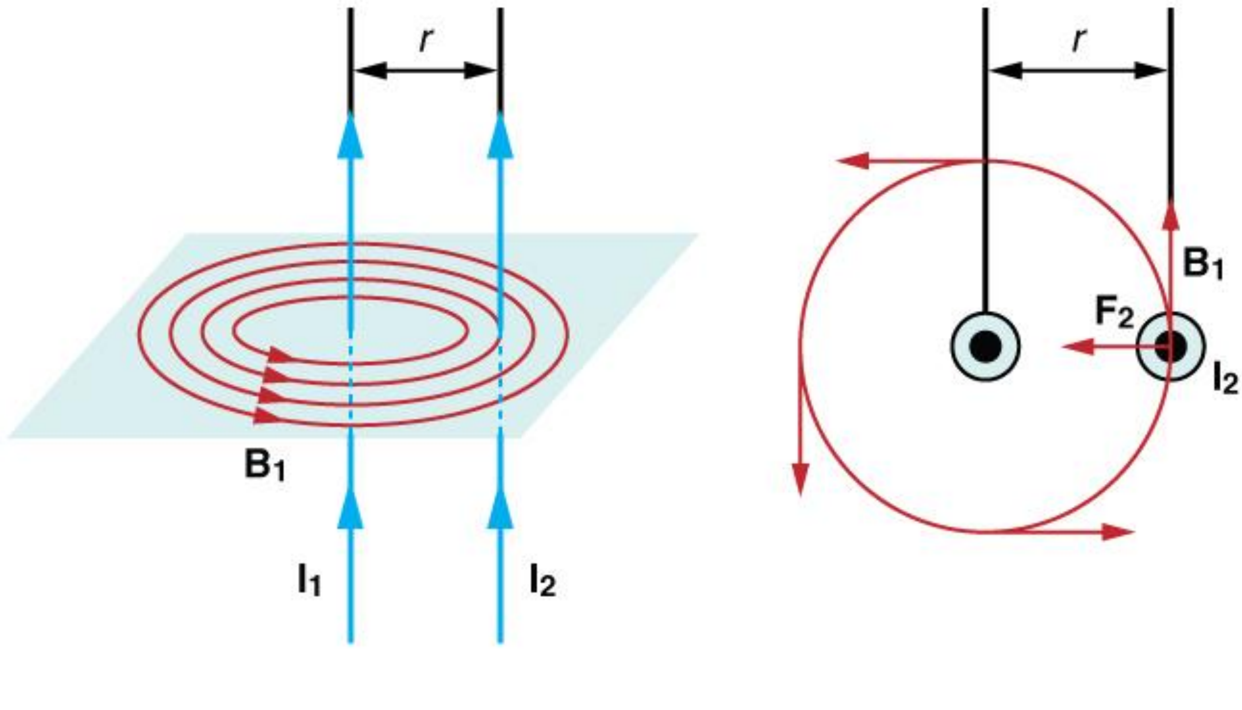


A left hand can be held, as shown in the illustration, so as to represent three mutually orthogonal axes on the thumb, forefinger, and middle finger. If we arrange the thumb, the center finger, and the forefinger of the left hand at right angles to each other, then the thumb points towards the direction of the magnetic force, the center finger gives the direction of current and the forefinger points in the direction of a magnetic field.

Magnetic Force between Two Parallel Conductors

The force between two long straight and parallel conductors separated by a distance *r* can be found by applying what we have developed in preceding sections. Figure 1 shows the wires, their currents, the fields they create, and the subsequent forces they exert on one another. Let us consider the field produced by wire 1 and the force it exerts on wire 2 (call the force F_2). The field due to I_1 at a distance *r* is given to be

$$B1=\mu 0I1/2\pi r$$



(a) (b)

This field is uniform along wire 2 and perpendicular to it, and so the force F_2 it exerts on wire 2 is given by F=IlBsinθ

with sinθ=1

F2=I2lB1

By Newton's third law, the forces on the wires are equal in magnitude, and so we just write *F* for the magnitude of F_2. (Note that $F_1=-F_2$.) Since the wires are very long, it is convenient to think in terms of *F*/*l*, the force per unit length. Substituting the expression for B_1 into the last equation and rearranging terms gives

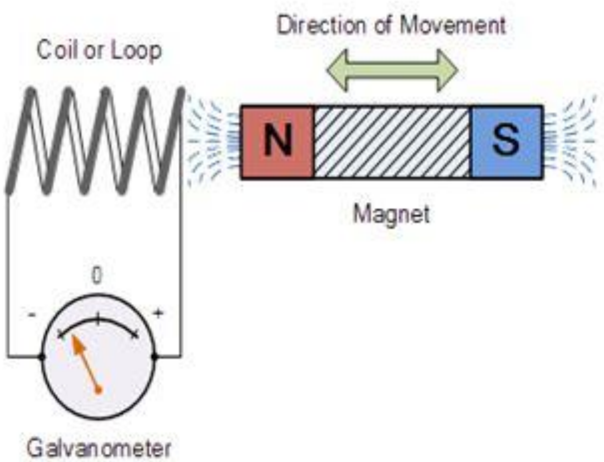
F/l=μ0I1I2/2πr.

Electromagnetic Induction

Electromagnetic Induction or Induction is a process in which a conductor is put in a particular position and magnetic field keeps varying or magnetic field is stationary and a conductor is moving. This produces a Voltage or EMF (Electromotive Force) across the electrical conductor. Michael Faraday discovered Law of Induction in 1830.

Suppose while shopping you go cashless and your parents use cards. The shopkeeper always scans or swipes the card. Shopkeeper does not take a photo of the card or tap it. Why does he swipe/scan it? And how does this swiping deduct money from the card? This happens because of the '**Electromagnetic Induction**'.

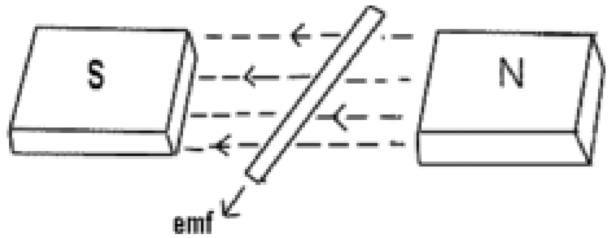
Can moving objects produce electric currents? How to determine a relationship between electricity and magnetism? Can you imagine the scenario if there were no computers, no telephones, no electric lights. The experiments of Faraday has led to the generation of generators and transformers.



The induction of an electromotive force by the motion of a conductor across a magnetic field or by a change in magnetic flux in a magnetic field is called **'Electromagnetic Induction'.**

This either happens when a conductor is set in a moving magnetic field (when utilizing AC power source) or when a conductor is always moving in a stationary magnetic field.

This law of electromagnetic induction was found by **Michael Faraday.** He organized a leading wire according to the setup given underneath, connected to a gadget to gauge the voltage over the circuit. So when a bar magnet passes through the snaking, the voltage is measured in the circuit. The importance of this is a way of producing electrical energy in a circuit by using magnetic fields and not just batteries anymore. The machines like generators, transformers also the motors work on the principle of electromagnetic induction. Faraday's law of Electromagnetic Induction



First law: Whenever a conductor is placed in a varying magnetic field, EMF induces and this emf is called an induced emf and if the conductor is a closed circuit than the induced current flow through it.

Second law: The magnitude of the induced EMF is equal to the rate of change of flux linkages.

Based on his experiments we now have Faraday's law of electromagnetic induction according to which the amount of voltage induced in a coil is proportional to the number of turns and the changing magnetic field of the coil.

So now, the induced voltage is as follows:

$$\mathbf{e = N \times d\Phi dt}$$

where, e is the induced voltage
N is the number of turns in the coil
Φ is the magnetic flux
t is the time

Lenz's law of Electromagnetic Induction

Lenz law of electromagnetic induction states that, when an emf induces according to Faraday's law, the polarity (direction) of that induced emf is such that it opposes the cause of its production.

According to Lenz's law

$$\mathbf{E = -N\,(d\Phi/\,dt)\quad (volts)}$$

What is Self Inductance?

Self-inductance is the property of the current-carrying coil that resists or opposes the change of current flowing through it. This occurs mainly due to the self-induced emf produced in the coil itself. In simple terms, we can also say that self-inductance is a phenomenon where there is the induction of a voltage in a current-carrying wire.

The self-induced emf present in the coil will resist the rise of current when the current increases and it will also resist the fall of current if the current decreases. In essence, the direction of the induced emf is opposite to the applied voltage if the current is increasing and the direction of the induced emf is in the same direction as the applied voltage if the current is falling.

The above property of the coil exists only for the changing current which is the alternating current and not for the direct or steady current. Self-inductance is always opposing the changing current and is measured in Henry (SI unit).

Induced current always opposes the change in current in the circuit, whether the change in the current is an increase or a decrease. Self-inductance is a type of electromagnetic induction.

Self-inductance Formula

We can derive an expression for the self-inductance of a coil from Faraday's law of electromagnetic induction.

$V_L = -N\ (d\phi / dt)$

Where:

V_L = induced voltage in volts

N = number of turns in the coil

$d\varphi / dt$ = rate of change of magnetic flux in webers / second

Alternatively, the induced voltage in an inductor may also be expressed in terms of the inductance (in henries) and the rate of change of current.

$V_L = -L\ (di / dt)$

Or

$E = -L\ (di / dt)$

Uses of Self Inductance

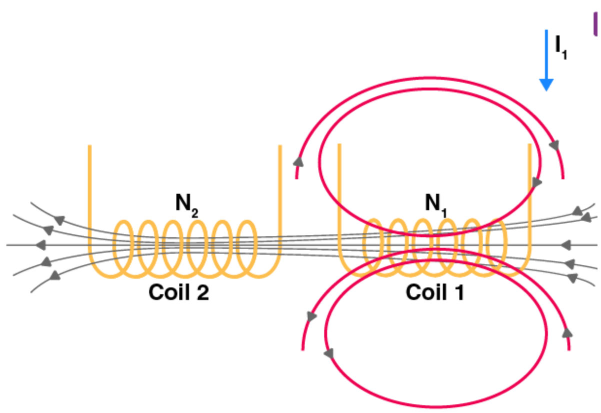
The major function of an inductor is to store electrical energy in the form of a magnetic field. Inductors are used in the following:

- Tuning circuits
- Sensors
- Store energy in a device

- Induction motors
- Transformers
- Filters
- Chokes
- Ferrite beads
- Inductors used as relays

What is Mutual inductance?

When two coils are brought in proximity with each other the magnetic field in one of the coils tend to link with the other. This further leads to the generation of voltage in the second coil. This property of a coil which affects or changes the current and voltage in a secondary coil is called mutual inductance.



For determining the Mutual Inductance between the two coils, the following expression is used

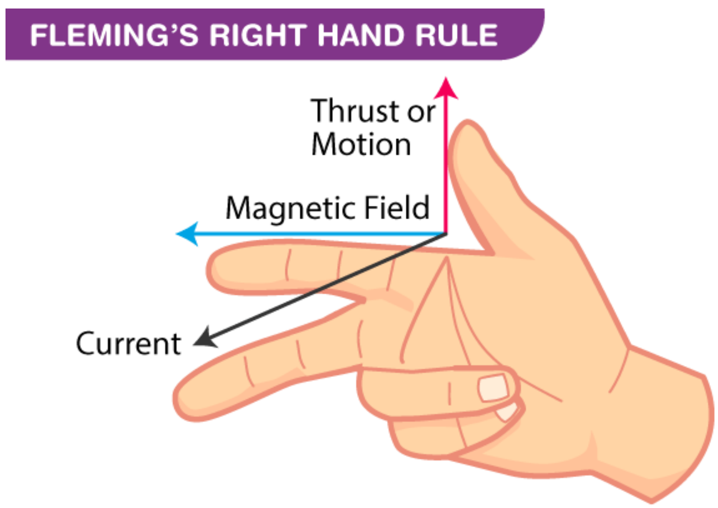
$$e_m = M\frac{dI_1}{dt}$$

or

$$M = \frac{e_m}{dI_1/dt} \quad \text{.........}(1)$$

This expression is used when the magnitude of mutually induced emf in the coil and the rate of change of current in the neighbouring coil is known.

When a current-carrying conductor is placed under a magnetic field, a force acts on the conductor. The direction of this force can be identified using ***Fleming's Left Hand Rule***. Likewise, if a moving conductor is brought under a magnetic field, electric current will be induced in that conductor. The direction of the induced current can be found using ***Fleming's Right Hand Rule***. It is important to note that these rules do not determine the magnitude, instead show only the direction of the three parameters (magnetic field, current, force) when the direction of the other two parameters is known. Fleming's Left-Hand Rule is mainly applicable to electric motors and Fleming's Right-Hand Rule is mainly applicable to electric generators.



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What is a Transformer?

A transformer is a device used in the power transmission of electric energy. The transmission current is AC. It is commonly used to increase or decrease the supply voltage without a change in the frequency of AC between circuits. The transformer works on basic principles of electromagnetic induction and mutual induction.

Based on Voltage Levels

Commonly used transformer type, depending upon voltage they are classified as:

- **Step-up Transformer:** They are used between the power generator and the power grid. The secondary output voltage is higher than the input voltage.
- **Step down Transformer:** These transformers are used to convert high voltage primary supply to low voltage secondary output.

Based on the Medium of Core Used

In a transformer, we will find different types of cores that are used.

- **Air core Transformer:** The flux linkage between primary and secondary winding is through the air. The coil or windings wound on the non-magnetic strip.
- **Iron core Transformer:** Windings are wound on multiple iron plates stacked together, which provides a perfect linkage path to generate flux.

Based on the Winding Arrangement

- **Autotransformer:** It will have only one winding wound over a laminated core. The primary and secondary share the same coil. Auto also means "self" in language Greek.

Based on Install Location

- **Power Transformer:** It is used at power generation stations as they are suitable for high voltage application
- **Distribution Transformer:** Mostly used at distribution lanes in domestic purposes. They are designed for carrying low voltages. It is very easy to install and characterized by low magnetic losses.
- **Measurement Transformers:** These are further classified. They are mainly used for measuring voltage, current, power.
- **Protection Transformers:** They are used for component protection purposes. In circuits some components must be protected from voltage fluctuation etc. protection transformers ensure component protection.

Based on Voltage Levels

Commonly used transformer type, depending upon voltage they are classified as:

- **Step-up Transformer:** They are used between the power generator and the power grid. The secondary output voltage is higher than the input voltage.
- **Step down Transformer:** These transformers are used to convert high voltage primary supply to low voltage secondary output.

Based on the Medium of Core Used

In a transformer, we will find different types of cores that are used.

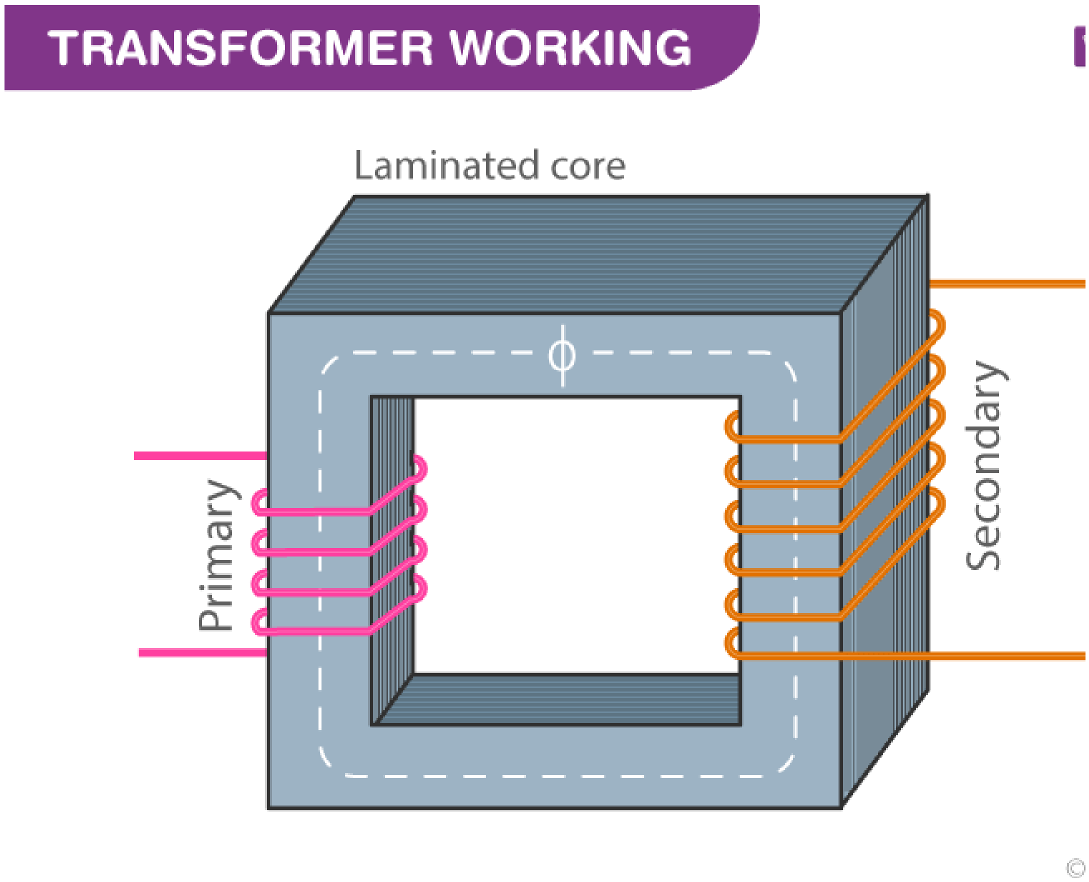
- **Air core Transformer:** The flux linkage between primary and secondary winding is through the air. The coil or windings wound on the non-magnetic strip.
- **Iron core Transformer:** Windings are wound on multiple iron plates stacked together, which provides a perfect linkage path to generate flux.

Based on the Winding Arrangement

- **Autotransformer:** It will have only one winding wound over a laminated core. The primary and secondary share the same coil. Auto also means "self" in language Greek.

Based on Install Location

- **Power Transformer:** It is used at power generation stations as they are suitable for high voltage application
- **Distribution Transformer:** Mostly used at distribution lanes in domestic purposes. They are designed for carrying low voltages. It is very easy to install and characterized by low magnetic losses.
- **Measurement Transformers:** These are further classified. They are mainly used for measuring voltage, current, power.
- **Protection Transformers:** They are used for component protection purposes. In circuits some components must be protected from voltage fluctuation etc. protection transformers ensure component protection.

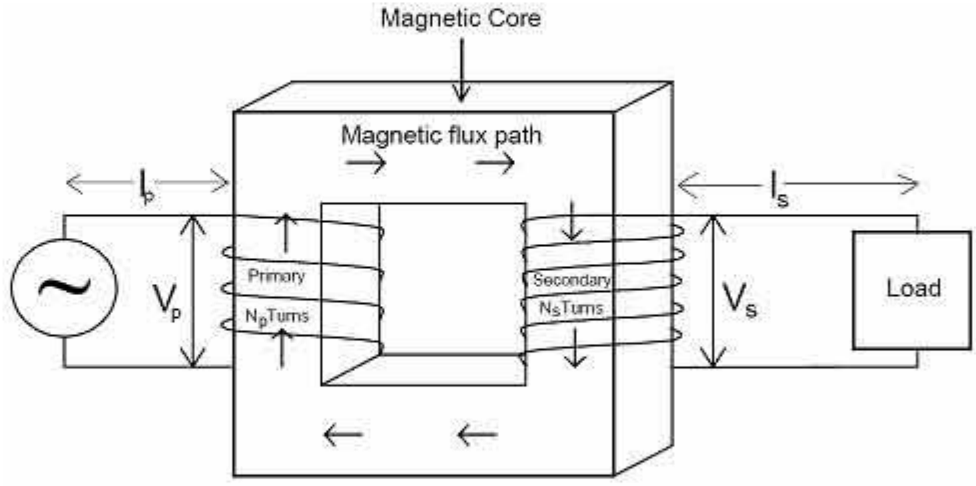


The transformer works on the principle of Faraday’s law of electromagnetic induction and mutual induction.

Lets us explain. There are usually two coils, primary coil and secondary coil on the transformer core. The core laminations are joined in the form of strips. The two coils have high mutual inductance. When an alternating current pass through the primary coil, forms a varying magnetic flux as per faraday’s law of electromagnetic induction and this change in magnetic flux induces an emf (electromotive force) in the secondary coil which is linked to the core having a primary coil. This is mutual induction.

Overall, a transformer carries the below operations:

1. Transfer of electrical energy from circuit to another
2. Transfer of electrical power through electromagnetic induction
3. Electric power transfer without any change in frequency
4. Two circuits are linked with mutual induction



An alternating voltage (V_p) applied to the PRIMARY creates an alternating current (I_p) through the primary.

This current produces an alternating magnetic flux in the magnetic core.

This alternating magnetic flux induces a voltage in each turn of the primary and in each turn of the SECONDARY.

As the flux is a constant e.g. the same in both primary and secondary: -

V_p = const N_p

V_s = const N_s

$$\therefore \quad \frac{V_s}{V_p} = \frac{N_s}{N_p}$$

This equation shows that a transformer can be used to step up or step down an ac voltage by controlling the ratio of primary to secondary turns. (Voltage transformer action).

It can also be shown that: -

Primary VoltAmperes = Secondary VoltAmperes

$V_pI_p = V_sI_s$

$$\therefore \; I_s = \frac{V_p}{V_s} I_p$$

$$As \;\; \frac{Vp}{Vs} = \frac{Np}{Ns}, \;\; we \; can \; write \;\; :-$$

$$I_s = \frac{N_p}{N_s} I_p$$

$$\therefore \quad \frac{Is}{Ip} = \frac{Np}{Ns}$$

This equation shows that a transformer can be used to step up or step down an ac current by controlling the ratio of primary to secondary turns. (Current transformer action)
It will be noted that there is no electrical connection between the primary and secondary windings.
A transformer therefore provides a means of isolating one electrical circuit from another.
These features - voltage/current transformation and isolation, cannot be obtained efficiently by any other means, with the result that transformers are used in almost every piece of electrical and electronic equipment in the world.

Types of Losses in a Transformer

There are different kinds of losses that will be occurred in the transformer such as iron, copper, hysteresis, eddy, stray & dielectric. The copper loss mainly occurs due to the resistance in the transformer winding whereas hysteresis losses will be occurred due to the magnetization change within the core.

Iron Losses in a Transformer

Iron losses mainly occur through the alternating flux within the transformer's core. Once this loss occurs within the core then it is called core loss. This kind of loss mainly depends on the material's magnetic properties within the core of the transformer. The core in the transformer can be made with iron, so these are called iron losses. This type of loss can be categorized into two types like hysteresis as well as eddy current.

Hysteresis Loss

This kind of loss mainly occurs when the alternating current is applied to the core of the transformer then the magnetic field will be reversed. This loss mainly depends on the core material used in the transformer. To reduce this loss, the high-grade core material can be used. CRGO- Cold rolled grain oriented Si steel can be used commonly like the core of the transformer so that Hysteresis loss can be reduced.

Eddy Current Loss

Once the flux is connected to a closed circuit, then an e.m.f can be induced within the circuit and there is a supply in the circuit. The flow of current value mainly depends on the sum of an e.m.f and resistance in the region of the circuit.
The core of the transformer can be designed with a conducting material. The flow of current in

the emf can be supplied within the body of the material. This flow of current is known as eddy current. This current will occur once the conductor experiences an altering magnetic field.

Stray Loss

These types of losses in a transformer can be occurred because of the occurrence of the leakage field. As compared with copper and iron losses, the percentage of stray losses are less, so these losses can be neglected.

Dielectric Loss

This loss mainly occurs within the oil of the transformer. Here oil is an insulating material. Once the oil in the transformer gets deteriorates otherwise when oil quality diminishes then the transformer's efficiency will be affected.

Applications and uses of Transformers

According to the necessity, transformers are classified into:

Power Transformers: These kinds of transformers are used for high voltage power transfer applications (more than 33 KV). They are usually bigger in size and can occupy larger space.

Distribution Transformers: These type of transformers are used to distribute the generated power to distant locations. It is used for distributing electricity at low voltage that is less than 33 KV in industry or 220-440 V for household purposes.

Measurement Transformers: This kind of uses of transformer helps in measuring voltage, current, and power, etc.

According to the place of use, transformers are classified into:

Indoor Transformers: These are covered with roofs and shelters just like the industry types.

Outdoor Transformers: These are mainly kept outside and are used as distribution type transformers.

While performing a manufacturing process, chemical engineering like electrolysis and electroplating is usually fueled by a regulated flow of current which is supplied with the help of a transformer. The current flow can be regulated according to the reaction.

During steel manufacturing process, high currents are required for melting and welding of steel and lower currents are required for cooling. Transformers provide a well regulated current during all these processes.

Transformers are also used for battery charging process. The voltage has to be controlled properly for not causing any damage to internal battery components which can be done only with the help of a transformer.

The presence of a transformer in a circuit breaker can help in starting and stopping the flow of current with the help of a switch and hence, protect from any damage due to a high voltage current.

One of the major uses of Transformers is for controlling the power of alternating current which helps in increasing efficiency and ultimately lowering the electricity bills.