UNIT 19 ELECTROMAGNETIC INDUCTION

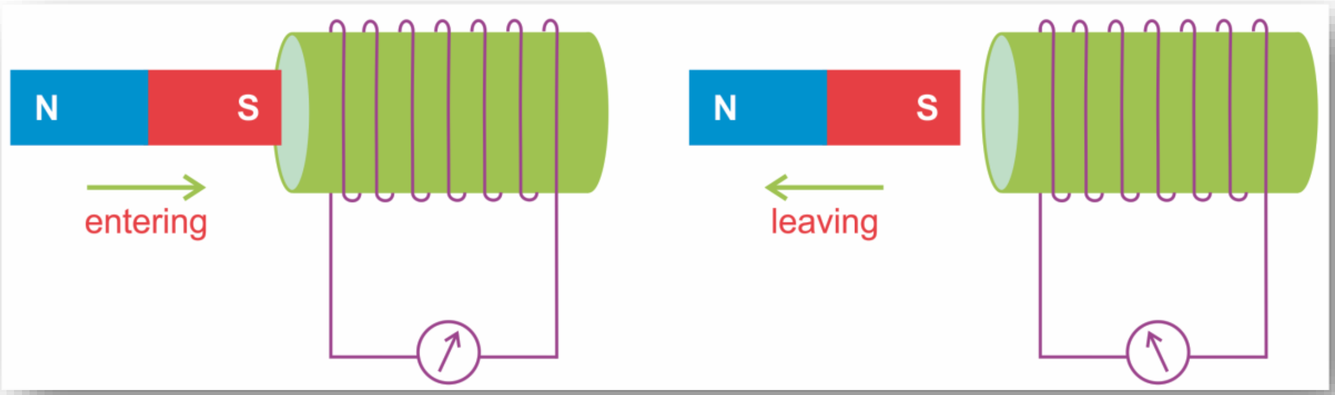
INTRODUCTION:

Electromagnetic induction stands as a cornerstone in the realm of physics, serving as Electromagnetic induction is a fundamental principle that explains the dynamic relationship between electricity and magnetism. The famous physicist Michael Faraday discovered in the early 19th century that electromagnetic induction encompasses the phenomenon where the change in the magnetic fields induces an electromotive force (EMF) or voltage within a conductor.

PRODUCTION OF ELECTRICITY BY MAGNETISM:

The moving magnet produces electric force. To observe this phenomenon, connect a Coil with a sensitive galvanometer, and a magnet moves inside it. The relative motion of the coil and motion will produce an induced electric current. If the motion of the magnet is stopped, the induced current ceases to exist.

The simple experiment shown in the Figure is similar to the work of an electric generator. The electric generator rotates the conductor coil within the permanent magnet field. The changing magnetic field produces an induced electric current. In 1831, Michael Faraday demonstrated that copper coils exposed to changing magnetic fields produced electric currents in the coils. Michael Faraday demonstrated this phenomenon with the help of a copper coil, a magnet, and a galvanometer. If the magnet was brought near the coil, an induced emf was produced, and the galvanometer showed current in one way. When the magnet was moved from the coil away, the direction of the induced current was reversed, and the galvanometer needle swung the other way. The phenomenon in which an EMF is induced in the coil due to the change in linking magnetic flux is called electromagnetic induction.



FARADAY'S LAW OF ELECTROMAGNETIC INDUCTION

Faraday's law of induction was discovered through experiments by Michael in England in 1831.

STATEMENT:

The electromotive force emf) induced in a closed circuit is directly proportional to the rate of change of magnetic flux passing through the circuit.

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MATHEMATICAL FORM :

If there are N turns of wire in a coil, each has an induced voltage that is in series with the other, so the net ***induced e.m.f*** (ξ) is

$$\xi = -N\frac{\Delta\Phi_m}{\Delta t}$$

One of the fundamental equations of electromagnetism is the induction law, which is generally known as Faraday's induction law.
The minus sign indicates the direction of induced ***emf***, determined by Len'z law.

FACTORS AFFECTING THE MAGNITUDE OF THE INDUCED EMF:

The magnitude of the induced electromotive force (emf) in a circuit or coil is governed by several factors primarily described by Faraday's law of electromagnetic induction. These factors include:

1. Magnetic Flux Change: If the rate of change of magnetic flux is higher, it will lead to a larger induced emf. Conversely, a slow change in the magnetic field will result in a smaller induced emf.
2. Number of Turns in the Coil: If a coil of wire has more turns, the induced emf will be greater. Each turn of the coil contributes to the emf, so increasing the number of turns increases the overall emf.
3. Area of the Coil: The size of the coil or the area it encloses also affects the induced emf. A larger coil or a coil with a larger cross-sectional area will capture more magnetic flux lines, resulting in a larger induced emf.
4 Angle between Magnetic Field and Coil: The angle between the magnetic field lines and the plane of the coil affects the induced EMF. The emf is maximized when the magnetic field is perpendicular to the coil's plane (90°). The emf is minimized when the field lines are parallel (0°).
5. External Factors: External factors, such as temperature, material property, pressure, and other environmental conditions can also influence the induced emf, especially when materials exhibit nonlinear magnetic properties.

LENZ LAW:

The rule for determining the directions of the induced current was proposed in 1834 by Heinrich Friedrich Emil Lenz (pronounced ***lents***)and is known as Lenz's law:

The induced emf will produce a current in a closed conduction loop that always acts to oppose the change that initially caused it.

EXPLANATION

In Figure (a), as the magnet's North Pole approaches the coil's surface, an induced current is generated in an anti-clockwise direction. Consequently, the coil generates a North magnetic pole, resulting in a repulsive force experienced by the approaching magnet. In this manner, the coil resists the factor responsible for inducing the electromotive force (emf).

In Figure (b), as the magnet's North Pole moves away from the coil, an induced current is generated within the coil in a clockwise direction. Consequently, the coil generates a South magnetic pole, resulting in an attractive force experienced by the leaving magnet. Hence, the law states that the induced current flows in a manner that opposes the change.

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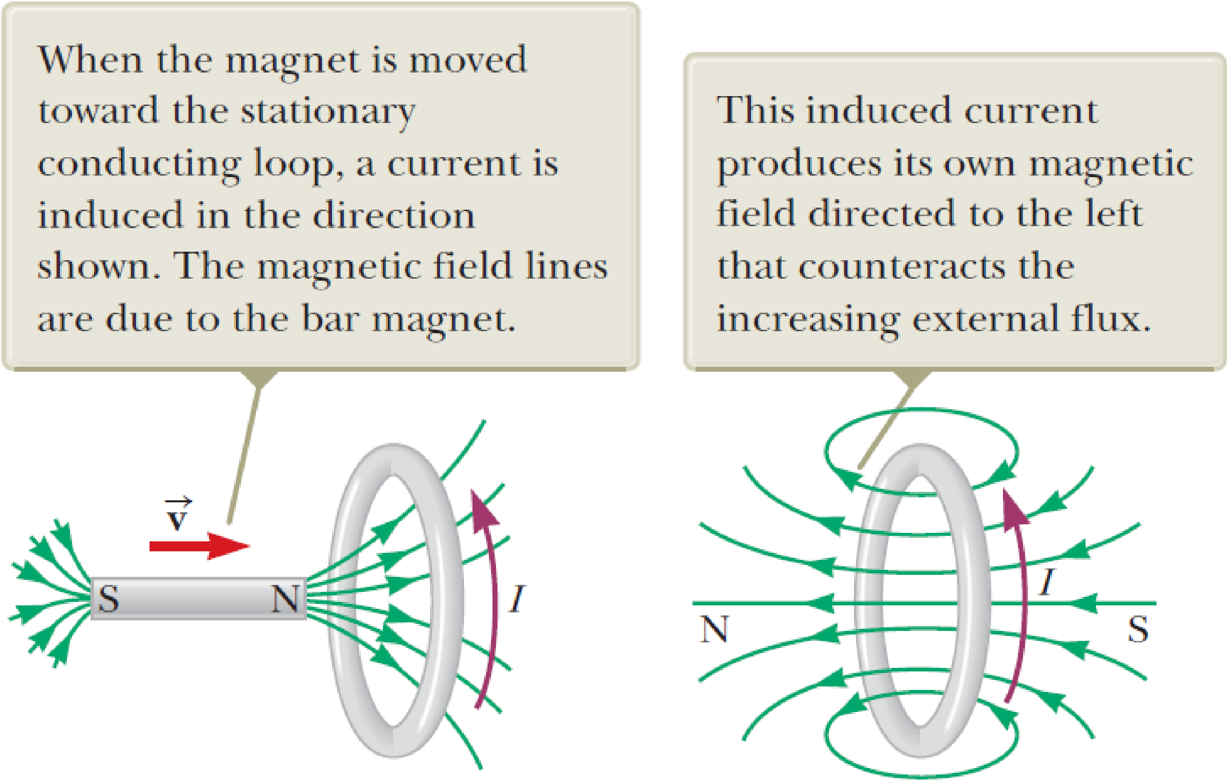
LENZ'S LAW IS A LAW OF CONSERVATION OF ENERGY:

The principle of conservation of energy states that energy cannot be created or destroyed; it can only change forms. When we apply this principle to electromagnetic induction, we see that the work done in changing the magnetic field is converted into electrical energy in the form of the induced current. Hence, Lenz's law follows the law of energy conservation.



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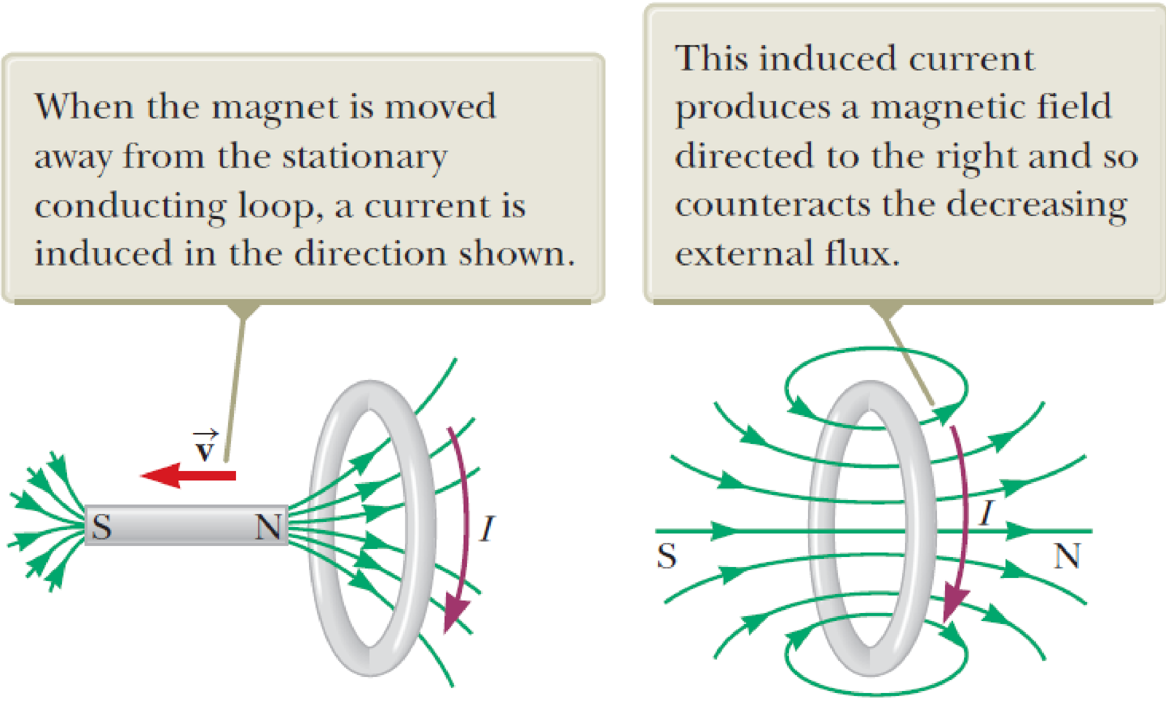

EDDY CURRENTS AND THEIR MAGNETIC AND HEATING EFFECTS:

Eddy currents are circulating currents induced in a conductor when exposed to a changing magnetic field. They are a common phenomenon in electromagnetic systems. These currents can have both magnetic and heating effects.

EDDY CURRENT

Eddy currents circulate in conductors like swirling eddies in a stream. They are induced by changing magnetic fields and flow in closed loops perpendicular to the plane of the magnetic field. They can be created when a conductor is moving through a magnetic field or when the magnetic field surrounding a stationary conductor is varying, i.e., anything which results in the conductor experiencing a change in the intensity or direction of a magnetic field can produce eddy currents. The size of the eddy current is proportional to the size of the magnetic field, the area of the loop, and the rate of change of magnetic flux and is inversely proportional to the resistivity of the conductor.

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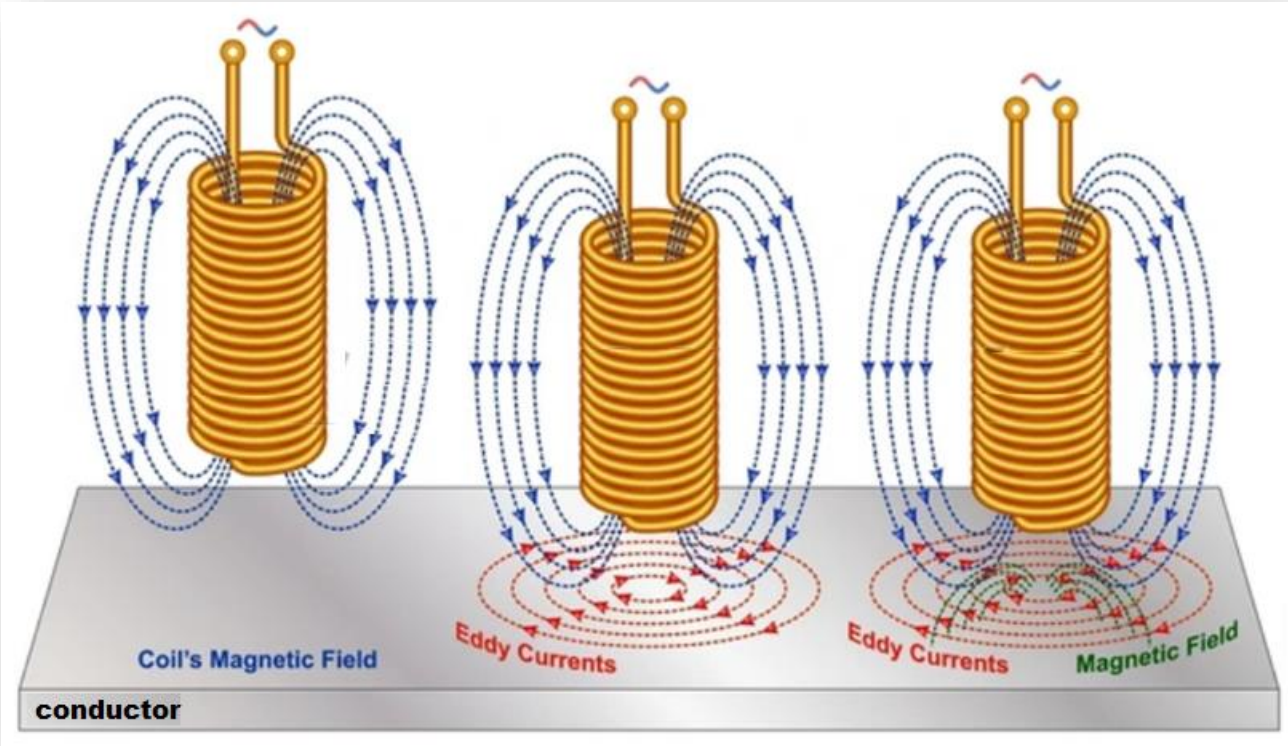


MAGNETIC EFFECTS OF EDDY CURRENTS:

Counteracting Magnetic Field:

Eddy currents generate their magnetic fields, and the direction of these fields opposes the original magnetic field that induced them. As a result, eddy currents create a magnetic field that counteracts the original magnetic field's change, thereby reducing the net magnetic field.

Magnetic Damping:

In applications like electromagnetic brakes and magnetic dampers, eddy currents are intentionally induced to create a magnetic resistance that opposes motion. This magnetic damping effect is useful for controlling and slowing objects' movement.

HEATING EFFECT OF EDDI CURRENT

Joule heating effect

Eddy currents experience resistance as they flow through the conductor, converting electrical energy into heat, following Joule's law. Eddy currents can heat the conductor. In some cases, such as induction heating for metal processing or cookware, this heating effect is used for practical applications.

Reduction of eddy current

Eddy currents represent an undesirable source of energy loss in many electrical systems, especially in transformers and electric motors. To minimize these losses, laminated cores are used in transformers to break up the conducting paths and reduce the formation of eddy currents.

The use of laminated iron cores in electric motors, generators, and transformers is essential for several important reasons:

In all three devices, the iron cores are exposed to alternating magnetic fields. When a solid iron core is used, it can create circular electrical currents within the core material called eddy currents. These eddy currents dissipate energy in the form of heat and can be highly inefficient. Laminated cores are constructed by stacking thin sheets or laminations of iron separated by insulating material. This design significantly reduces the formation of eddy currents because the laminations are electrically insulated from each other. Consequently, energy losses due to eddy currents are minimized.

Enhance efficiency

Laminated cores improve the efficiency of electric motors, generators, and transformers by reducing the losses associated with eddy currents. Less energy is wasted as heat, allowing these devices to operate more efficiently and with less energy consumption.

Mitigation of vibration and noise

Eddy currents generated in a solid iron core can lead to vibrations and noise, which can be undesirable in many applications. Laminated cores help reduce these vibrations and noise levels, making the devices quieter and more mechanically stable.

Better cooling and thermal management

Since laminated cores reduce heat generation due to decreased eddy current losses, they often allow for more efficient cooling and thermal management in these devices. This can lead to longer operational lifetimes and improved reliability.

SELF INDUCTION

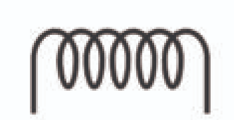
A phenomenon in which a changing current in a coil induces an e.m.f in itself is called self-induction. According to Lenz's law, the e.m.f opposes the change that has induced it, which is, therefore, known as back e.m.f.

SELF INDUCTANCE:

The ability of a coil to produce back emf is called self-inductance. It works on the principle of electromagnetic induction.

CIRCUIT SYMBOL:

A device used in the circuit to produce back EMF is called an inductor, which is represented by, which resembles the shape of a solenoid.



MATHEMATICAL EXPRESSION

The self-induced emf in a coil is directly proportional to the time rate of current change.

$$\varepsilon \ \alpha \ -\frac{\Delta I}{\Delta t}$$

$$\varepsilon = -L\frac{\Delta I}{\Delta t} \dots\dots..(i)$$

Where L is a proportionality constant called the inductance of the device, the negative sign indicates that the changing current induces an e.m.f in opposition to that change.

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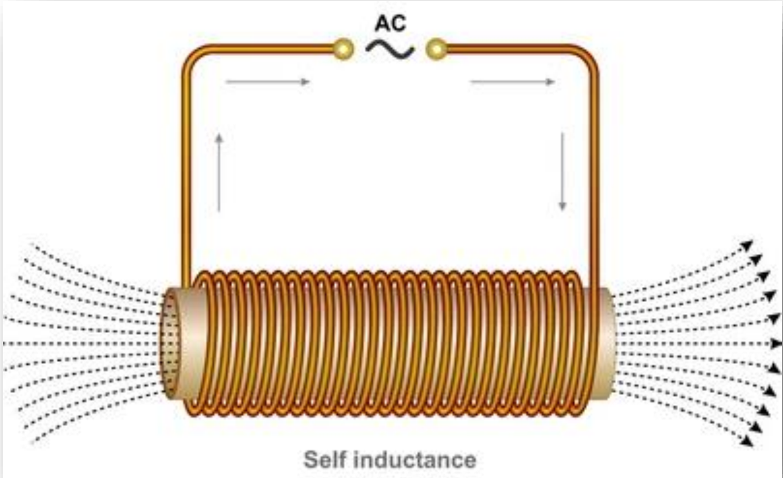

This means that if the current is increasing (ΔI positive), the induced emf is negative to indicate opposition to the increase. Likewise, if the current is decreasing (ΔI negative), the sign of the induced emf to positive indicates that the emf is acting to oppose the decrease.

The inductance of a coil depends on its cross-sectional area and other quantities, all of which can be grouped under the general heading of geometric factors (such as the size, shape, and number of turns of the coil).

By the Faradays law of electromagnetic induction

$$\varepsilon = -N \frac{\Delta\Phi}{\Delta t} \dots\dots (ii)$$

Comparing equation (i) and (ii), we get

$$-\mathrm{L} \frac{\Delta \mathrm{I}}{\Delta \mathrm{t}} = -N \frac{\Delta\Phi}{\Delta t}$$

$$\mathrm{L}\,\Delta\mathrm{I} = N\,\Delta\Phi$$

$$\mathrm{L}\,\Delta\mathrm{I} = N\,\Delta\Phi$$

UNIT:

The SI unit of inductance is the Henry **(H)**

$$1\,H = 1 \frac{volt.second}{ampere}$$

$$1\,H = 1 \frac{volt}{ampere\ per\ second}$$

The self-inductance of a coil is one henry if a current change of one ampere per sec induces an emf of one volt in itself.

ENERGY STORED IN INDUCTOR

An inductor is a passive electrical component that stores energy as a magnetic field when an electric current flows through it. The ability of an inductor to store electric potential energy is based on the fundamental principle of electromagnetic induction.

Here's a simple explanation of how an inductor stores electric potential energy:

Current Flow:

When an electric current flows through a coil of wire (the inductor), it creates a magnetic field around the coil.

Magnetic Field Buildup:

As the current increases, the strength of the magnetic field around the coil also increases. This process takes a short time, as the magnetic field does not build up instantly; it grows with the current rate of change.

Energy Storage:

The energy is stored in the magnetic field. The inductor stores electric potential energy in this magnetic field. The more current flows through the inductor or the faster the current changes, the stronger the magnetic field; thus, the more energy is stored.

Magnetic Field Collapse:

The magnetic field collapses when the current decreases or stops (like when you turn off the power). This induces an electromotive force (EMF) or voltage in the coil.

Released Energy

This induced voltage represents the stored energy being released. The inductor converts the stored magnetic energy back into electrical energy. This energy can sustain the current for a short period or transferred to other parts of the circuit.

ENERGY PRODUCED IN SELF INDUCTION

An inductor stores energy in its magnetic field by carrying a direct current (DC). This energy remains stored as long as the inductor continues to carry the current. When the current in the inductor increases, the stored energy also increases; conversely, it decreases when the current is reduced. Consider an inductor connected to a DC power source through a switch, as depicted in Figure 19.7. When the switch is closed, the current in the inductor gradually rises until it reaches its maximum value, denoted as I. This changing current leads to a corresponding change in the magnetic flux within the coil, causing an induced electromotive force (emf) to establish itself in the coil. Consequently, an induced current is generated in the circuit, which works to minimize the current produced by the battery following Lenz's law.

As a result, the battery must perform work on the charges to build up the current T.his work is mathematically expressed as follows:

$$W = \Delta V \, \Delta q \, \dots\dots (i)$$

As the induced emf is produced in the inductor, it is given as:

$$\Delta V = \varepsilon_L = L \frac{\Delta I}{\Delta t} \dots\dots (ii)$$

Substituting the expression for emf in equation (i)

$$W = \frac{\Delta q}{\Delta t} L \, \Delta I$$

$$E = \frac{\Delta q}{\Delta t} L \, I \dots\dots (iii)$$

Since

$$\frac{\Delta q}{\Delta t} = \frac{0 + I}{2}$$

$$\frac{\Delta q}{\Delta t} = \frac{I}{2}$$

Equation (iii) become

$$E = \left(\frac{I}{2}\right) L\, I$$

$$E = \frac{1}{2} L\, I^2$$

This formula tells you that the energy stored in an inductor is directly proportional to the square of the current passing through it and depends on the inductor's inductance.

MUTUAL INDUCTION

A phenomenon in which a changing current in one coil induces an EMF in the other coil is known as mutual induction. The coil in which the current is changed is called the primary coil, and the other is called the secondary one.

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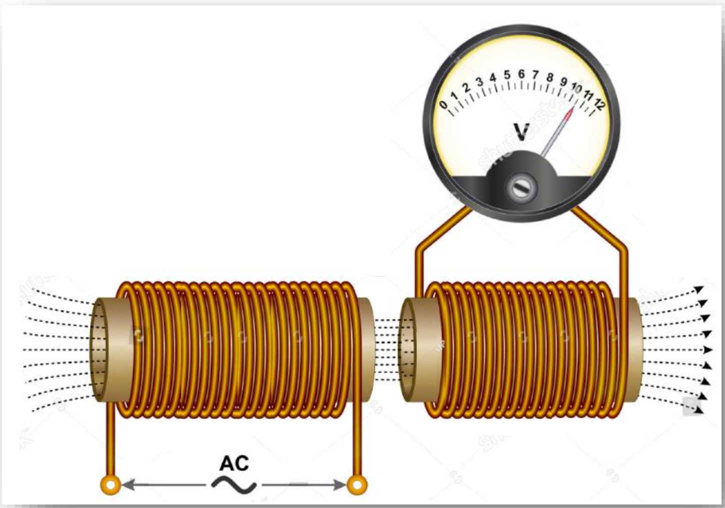

MUTUAL INDUCTANCE:

The ability of a pair of coils to induce an electromotive force (emf) in one of the coils by changing the current in the other is called mutual inductance

MATHEMATICAL EXPRESSION:

The induced emf in the secondary coil is directly proportional to the current change rate in the primary coil.

$$\varepsilon_S \;\alpha - \left(\frac{\Delta I_P}{\Delta t}\right)$$

$$\varepsilon_S = -M \left(\frac{\Delta I_P}{\Delta t}\right) \ldots \ldots (i)$$

Where ‘M’ is a constant called mutual inductance. The negative sign is by Lenz’s law.

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According to Faraday's law of electromagnetic induction

$$\varepsilon_s = -N_s \frac{\Delta\Phi_s}{\Delta t} \dots\dots (ii)$$

Comparing equation (i) and (ii), we get

$$-M\left(\frac{\Delta I_P}{\Delta t}\right) = -N_s \frac{\Delta\Phi_s}{\Delta t}$$

$$\mathrm{M}\,\Delta \mathrm{I}_P = N_s\,\Delta\Phi_s$$

UNIT:

The SI unit of inductance is the Henry (H).

$$1\,H = 1\,\frac{volt.second}{ampere}$$

$$1\,H = 1\,\frac{volt}{ampere\ per\ second}$$

If a current change of 1A/Sec in the primary coil induces an emf of 1 volt in the secondary coil, the mutual inductance of the two coils is 1 Henry.

TRANSFORMER

A transformer transfers electrical energy from one circuit to another and converts alternating current at high voltage into low voltage and vice versa.

PRINCIPLE

When current changes in a coil (called a primary coil), its changing flux induces an emf in a nearby coil (called a secondary coil). This phenomenon is known as "Mutual induction."

CONSTRUCTION

It consists of the following parts:

(i) Two Coils

Two coils of copper wires well insulated from each other are wound on a soft-iron core. The coil to which electrical energy is supplied is called the "primary coil," and that from which power is delivered to the outer circuit is called the "secondary coil."

(ii) Core

A laminated core of a special steel alloy with high resistance and low hysteresis loss is used. To reduce energy losses, each lamination is insulated from the other by varnish or enamel.

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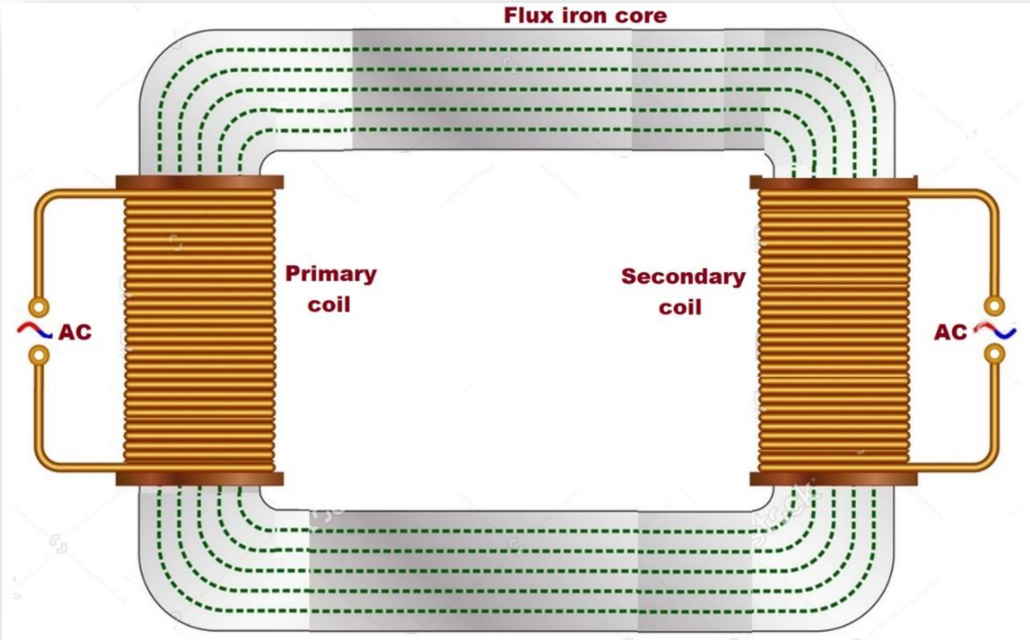

WORKING

Let an alternating voltage V_p be applied across the "primary coil ."The resulting current I_P gives rise to a varying flux in the core. This varying flux induces an opposing emf in the primary coil (which is equal to the applied voltage if the resistance of the coil is negligible). Hence, V_p is given by the flux linkage. Using Faraday's law, we have

$$V_P = -N_P \frac{\Delta\Phi}{\Delta t} \ldots\ldots\ldots\ldots(i)$$

$$V_P = N_P \frac{\Delta\Phi}{\Delta t} \text{ --------------- } (1)$$

Where Np represents the number of turns of the primary coil. At the same time, the varying flux passes through the secondary and induced emf. is

$$V_s = -N_s \frac{\Delta\Phi}{\Delta t} \ldots\ldots\ldots(ii)$$

Where Ns is the number of turns of the secondary coil.

Dividing eq. (ii) by (i), we have

$$\frac{V_s}{V_P} = \frac{-N_s \frac{\Delta\Phi}{\Delta t}}{-N_P \frac{\Delta\Phi}{\Delta t}}$$

$$\frac{V_s}{V_P} = \frac{N_s}{N_P} \ldots\ldots\ldots(iii)$$

The ratio Ns/Np is called the "turns ratio."

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POWER DISSIPATION

For an ideal case, the power input to the primary is equal to the power output from the secondary, i.e.

$$P_S = P_P$$

$$V_S I_S = V_P I_P$$

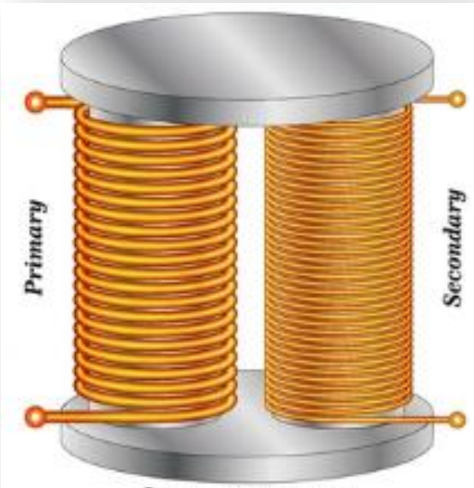
$$\frac{I_S}{I_P} = \frac{V_P}{V_S}$$

$$\frac{V_P}{V_S} = \frac{I_S}{I_P}$$

Thus, currents are inversely proportional to the respective voltages. Hence, voltage is raised at the cost of reducing current.

STEP UP TRANSFORMER:

Step-up transformers are designed to increase the voltage of electricity. They have more turns in the secondary coil than the primary one, resulting in a higher secondary voltage than the primary one.



Step-up transformer

Reduced Current:

Increasing the voltage through a step-up transformer reduces the current while maintaining the same power (P = VI). Lower current reduces the resistive losses in the transmission cables. The power
lost as heat (FR losses) is proportional to the square of the current, so decreasing the current significantly reduces these losses.

Efficient Long-Distance Transmission:

High voltage is essential for efficient long-distance power transmission. Step-up transformers are used at power generation plants to raise the voltage, allowing electricity to be transported over extensive electrical grids with minimal energy loss. This is especially important for transmission lines covering large distances.

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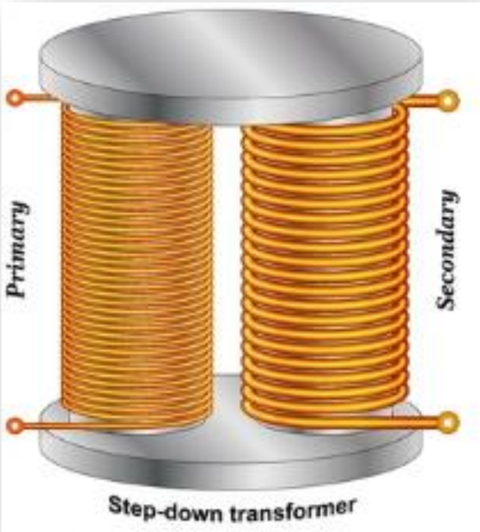
STEP-DOWN TRANSFORMERS:

This transformer changes an alternating voltage to a lower value, i.e., Vs< Vp. But we must have $I_s < I_p$. It is achieved when the secondary coil has fewer turns than the primary coil. Thus Ns < Np



Voltage Reduction:

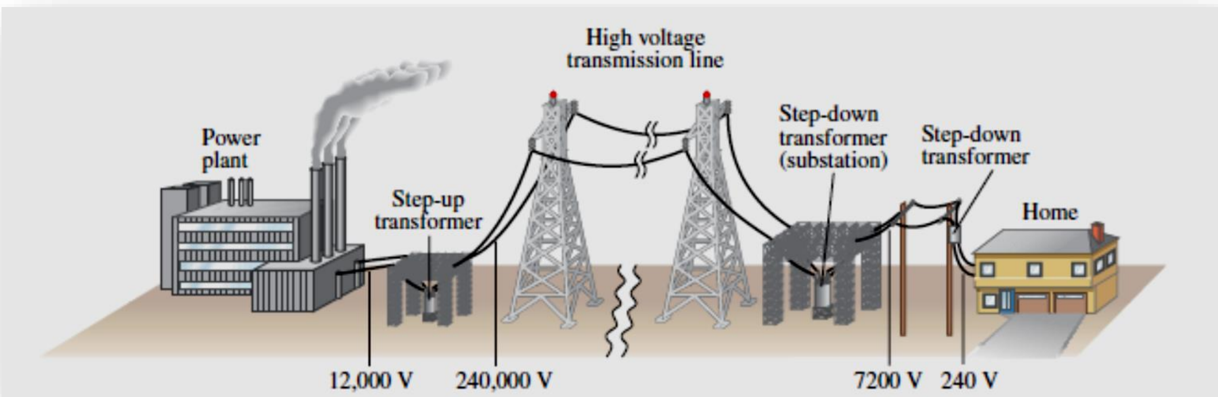
On the other hand, step-down transformers lower the voltage from high levels to safer, more usable levels for homes and industries. They have fewer turns in the secondary coil, which decreases the secondary voltage.

Balanced Current:

While step-down transformers decrease voltage, they increase the current to maintain the same power. This benefits local distribution by ensuring power can be delivered to homes, businesses, and industrial facilities while minimizing FR losses over shorter distances.

TRANSMISSION OF ELECTRICITY:

Step-down and step-up transformers are used for the electric supply from power stations to houses and electric appliances. Here's how they are used in the electric supply process, as shown in Figure



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1. Power Generation at the Station:

Electricity is generated at power stations, often using generators powered by various sources such as hydel, coal, natural gas, nuclear energy, or renewable sources like wind and solar. The electricity generated is typically produced at a relatively low voltage level. Higher voltages are preferred to minimize energy losses for efficient
generation and long-distance transmission.

2. Step-Up Transformers at the Power Station:

Step-up transformers are employed at the power station to raise the voltage to levels suitable for long-distance transmission. Step-up transformers increase the voltage and reduce the current, which lowers the FR losses, making electricity transmission more efficient. High-voltage transmission lines, such as overhead power lines or underground cables, carry the electricity over long distances to substations.

3. Transmission and Substations:

The high-voltage electricity is transmitted over transm1ss10n lines to substations at various points in the electricity distribution network. Step- down transformers are used at these substations to lower the voltage to a more manageable level for further distribution.

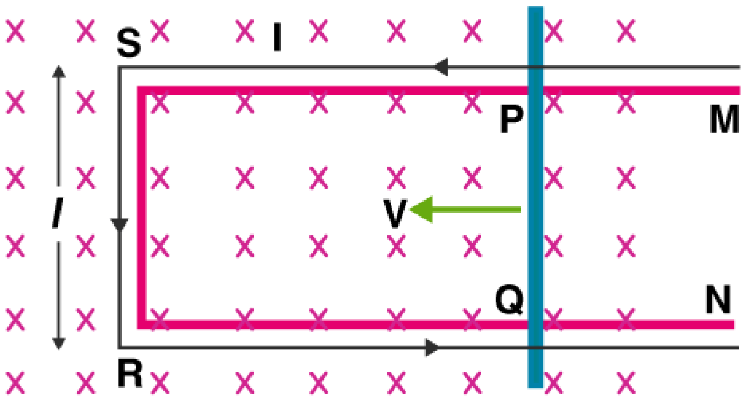
4. Step-Down Transformers in Substations:

Step-down transformers reduce the high-voltage electricity to lower, safer voltage levels suitable for local distribution. This lower voltage is then distributed to houses through distribution lines.

Motional emf:

Motional electromotive force (emf) is a phenomenon that arises when a conductor moves through a magnetic field, inducing an electromotive force within the conductor. This concept is based on Faraday's law of electromagnetic induction and is a fundamental aspect of electromagnetism.

Consider a straight wire PQ with length L, as shown in the Figure.



The conductor is in motion within a rectangular loop PQRS. This motion occurs within a uniform magnetic field B, perpendicular to the plane of the page. We assume the rod moves uniformly at a constant velocity of v meters per second. Each free electron of the conductor moves with the conductor and thus experiences a force.

$$F = q\left(\vec{v} \times \vec{B}\right)$$

$$F = e\left(\vec{v} \times \vec{B}\right)$$

$$F = e\,v\,B\ \sin\theta \ldots\ldots (i)$$

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Electrons accumulate at one end of the conductor, creating an excess of electrons, which results in a negative charge at that end. Conversely, the opposite end, with a deficiency of electrons, leads to the development of a positive charge. This process generates a potential difference within the wire, called motional electromotive force (emf).

We use the definition of potential difference to derive an expression for the motional emf. $\text{potential difference} = \frac{\text{work}}{\text{charge}}$

$$V = \frac{W}{q}$$

$$V = \frac{F\,L}{e} \;\ldots\ldots (ii)$$

Substituting the expression for force in equation (ii)

$$V = \frac{e\,v\,B\ \sin\theta\ L}{e}$$

$$V = v\,BL\ \sin\theta$$

If the conductor is moving at the right angle to the magnetic field, then 0 = 90°

$$V = v\,BL\ \sin 90^0$$

$$V = v\,BL$$

AC GENERATOR

A device that converts mechanical energy into electrical energy is called **an AC generator** or **dynamo.**

CIRCUIT SYMBOL:

In a circuit, the symbol for a source of alternating emf(AC generator)  is

PRINCIPLE:

It works on the principle of electromagnetic induction. An EMF is induced when a coil is rotated in a magnetic field.

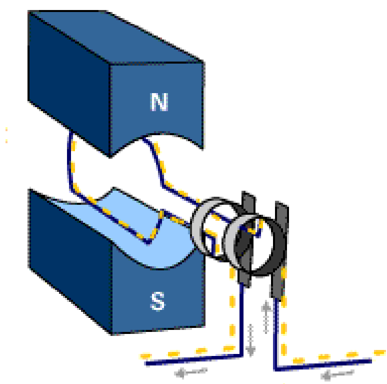
CONSTRUCTION:

The following are the essential parts of an AC generator:

1 **FIELD MAGNET**:
is a permanent strong magnet with curved poles to produce a radial magnetic field.

2 **ARMATURE:**
A coil of insulated copper with **N** turns is wound on a soft iron cylindrical core. The coil and its core are collectively called an armature.

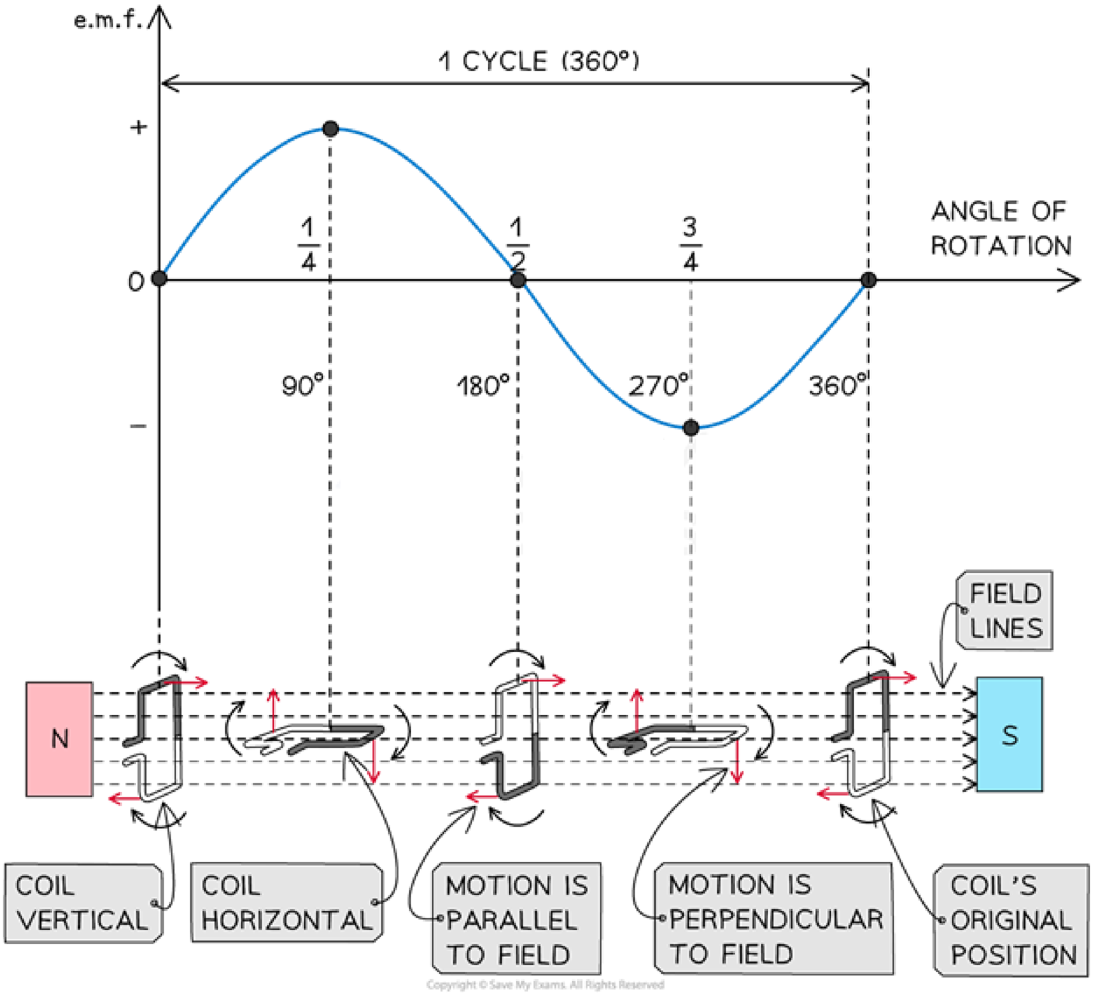
3 **SLIP RINGS AND BRUSHES:**
The ends of the rotor coil are connected to slip rings, which are conductive rings that rotate with the rotor. Typically made of graphite, brushes press against the slip rings to collect the generated electrical current.



4 **Shaft and Bearings**:
The rotor is mounted on a shaft that allows it to rotate freely. Bearings are used to reduce friction and enable smooth rotation.

Induced EMF of an AC generator:

Suppose the armature coil rotates counterclockwise. As it rotates, the magnetic flux linked with it changes, inducing a current in the coil, as shown in the Figure.



Alternating e.m.f. with corresponding positions of the coil relative to the field

- When the coil is vertical at 0°
  - it is moving **parallel** to the direction of the magnetic field
  - the size of the induced e.m.f. is **zero**
- When the coil has rotated by 90°
  - it is now **horizontal** and moving **perpendicular** to the direction of the magnetic field
  - the size of the induced e.m.f. is at a **maximum**
- When the coil has rotated by 180°
  - it is **vertical** again and moving **parallel** to the direction of the magnetic field
  - the size of the induced e.m.f. is **zero**

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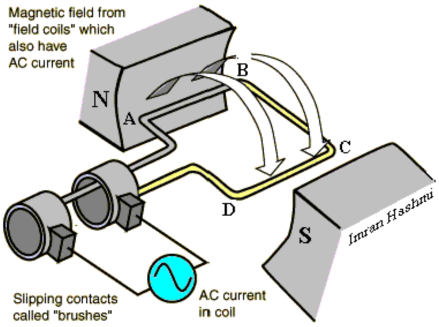
- When the coil has rotated by 270°
  - it is **horizontal** again and moving **perpendicular** to the direction of the magnetic field
  - the size of the induced e.m.f. is at a **maximum** and in the **opposite** direction to its position at 90°

- When the coil has completed a full 360° rotation
  - it is back at its starting point, where it is moving **parallel** to the direction of the magnetic field
  - the size of the induced e.m.f. is **zero**

EXPRESSION FOR EMF



We can derive an expression for the emf generated in the rotating loop by using the expression for motional emf, ξ = BLv. The Figure shows a wire loop rotating clockwise in a uniform magnetic field directed to the right.
Now,

$$Motional\ emf\ in\ AB = BL\,vSin\theta$$

$$Motional\ emf\ in\ CD = BLvin\theta$$

The total induced EMF in the coil is

$$Induced\ emf\ in\ coil = 2B\,L\,v\,Sin\theta \ldots\ldots\ldots\ldots(i)$$

If the loop rotated with a constant angular speed ω,

$$v = r\,\omega = \quad r = \frac{b}{2},$$

$$v = \frac{b}{2}\,\omega$$

where b is the width of a side AB and C; therefore, equation (i) reduces to

$$emf = 2\,BL\left(\frac{b}{2}\,\omega\right)Sin\omega t$$

$$emf = BL\,(b\,\omega)Sin\omega t$$

$$emf = B(L \times b)\,\omega\,Sin\omega t$$

If a coil has N turns, the emf is N times larger because each loop has the same emf induced. Furthermore, because the area of the loop is A = Lb, the total emf is

$$\varepsilon = NBA\,\omega\,Sin\omega t$$

The result shows that the emf varies sinusoidal with time; the maximum emf has the value

$$\varepsilon_{maximum} = NBA\omega$$

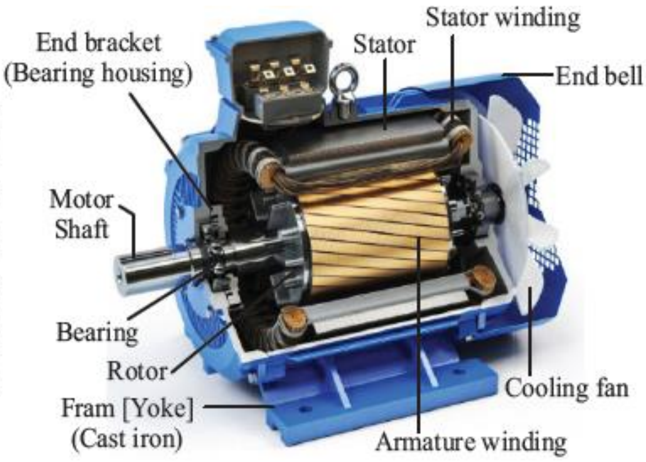
$$\varepsilon = \varepsilon_{maximum}\,Sin\omega t$$

In terms of frequency, this can be written as

$$\varepsilon = \varepsilon_{maximum}\,Sin2\,\pi\,ft \qquad [\ \omega = 2\pi f\ ]$$

UNIT 19 ELECTROMAGNETIC INDUCTION

AC Motor:
An AC (Alternating Current) motor is designed to convert electrical energy into mechanical energy using alternating current. There are various types of AC motors, but the main features And components are generally consistent across different designs. The primary components, as shown in the Figure, and their roles in an AC motor are as follows:



Stator:
The stator is the stationary part of the motor and contains the primary windings. When AC voltage is applied, it produces a rotating magnetic field that interacts with the rotor to induce motion.

Rotor:
The rotor is the rotating part of the motor. Depending on the motor design, it can be of different types, such as squirrel- cage
or wound rotor. When the stator produces a rotating magnetic field, the rotor experiences a torque due to the interaction with the field. This torque causes the rotor to rotate and generate mechanical output.

Bearings:
Bearings are essential components that support and allow the rotor to rotate within the stator. They reduce friction, enabling smooth and efficient operation of the motor.

Shaft: The shaft is connected to the rotor and extends beyond the motor housing. It transfers mechanical energy to the outside world, allowing the motor to perform helpful work when connected to a load.

Cooling System:
Many AC motors incorporate cooling systems, such as fans or fins, to dissipate heat generated during operation. Efficient cooling is essential to prevent overheating and prolong the motor's lifespan.

The main features and components work together to enable the AC motor to function. When AC voltage is applied to the stator windings, a rotating magnetic field is created, exerting torque on the rotor. The rotor's rotation results in mechanical work being performed by the motor, which can be used to drive various mechanical devices, such as fans, pumps, conveyor belts, and more.

The production of back emf in electric motors:
Back electromotive force (back EMF) is fundamental to understanding motor operation and efficiency in electric motors. Back EMF is a self-generated electromotive force that opposes the applied voltage in a motor. It plays a crucial role in motor behavior, especially in limiting current and regulating speed. Here's a detailed explanation of the concept of back EMF in electric motors:

UNIT 19

ELECTROMAGNETIC INDUCTION

Electromagnetic Induction:

Back EMF is a consequence of Faraday's law of electromagnetic induction, which states that a change in magnetic flux through a coil of wire induces an electromotive force (EMF) in that coil. In an electric motor, the coil of wire is typically part of the rotor or armature.

Rotating Magnetic Field:

When an electric motor is powered, the stator (the stationary part of the motor) generates a rotating magnetic field by applying an alternating current (AC) voltage to its windings. In a direct current (DC) motor, the commutator and brushes create a changing magnetic field.

Rotor or Armature Interaction:

The motor's rotor (or armature) is mounted within the magnetic field created by the stator. As the rotor rotates, it cuts through the magnetic field lines, causing a change in magnetic flux within the wire coils on the rotor.

Back EMF Generation:

The change in magnetic flux through the rotor windings induces a voltage, which is referred to as back EMF. The direction of the induced voltage is in opposition to the applied voltage. In other words, it generates a voltage that resists the current flow through the motor windings.

Current Regulation:

Back EMF has a critical function in motor operation. As the motor speeds up, the back EMF increases. This increase in back EMF results in a decrease in the net voltage across the motor windings. Consequently, the current flowing through the motor decreases. This self- regulation mechanism is essential for preventing the motor from drawing excessive current, overheating, and potentially damaging itself.

Effect on Motor Speed:

The relationship between back EMF and motor speed is inverse. When the motor operates at a higher speed, the back EMF is more significant, and the current is reduced, helping maintain a consistent speed. Conversely, at lower speeds or when subjected to a higher mechanical load, the back EMF decreases, allowing more current to flow and providing the necessary torque to overcome the load.

In summary, the concept of back EMF in electric motors is the self-induced voltage that opposes the applied voltage and helps regulate the current and speed of the motor. It is a critical factor in ensuring the safe and efficient operation of electric motors, and understanding it is essential for motor design and performance analysis.