Unit - 16
Electromagnetism

Students Learning Outcomes (SLOs)
After learning this unit students should be able to

- Explain by describing an experiment that an electric current in a conductor produces a magnetic field around it.
- Define Magnetic field
- Sketch the lines of magnetic force
- Describe that a force acts on a current carrying conductor placed in a magnetic field as long as the conductor is not parallel to the magnetic field.
- State that a current carrying coil in a magnetic field experiences a torque.
- Relate the turning effect on a coil to the action of a D.C. motor
- Describe an experiment to show that a changing magnetic field can induce e.m.f. in a circuit.
- List factors affecting the magnitude of an induced e.m.f.
- Explain that the direction of an induced e.m.f opposes the change causing it and relate this phenomenon to conservation of energy
- Describe a simple form of A.C generator.
- Describe mutual induction and state its units
- Identify that a transformer works on the principle of mutual induction between two coils
- Describe the purpose of transformers in A.C circuits
- Identify the role of transformers in power transmission from power station to your house.
- List the use of transformer (step -up and step-down) for various purposes in your home

There is a strong connection between electricity and magnetism. The production of electricity using a magnet as a source is an interesting occurrence. It is possible to generate electric current by changing magnetic field, and likewise, magnetic fields can be generated by changing electrical current. A simple magnet can be used to produce a life-changing technology which makes life easier.

The four fundamental forces act upon us every day, whether we realize it or not. From playing basketball, to launching a rocket into space, to sticking a magnet on your refrigerator - all the forces that all of us experience every day can be whittled down to a critical quartet: Gravity, the weak force, electromagnetism, and the strong force. These forces govern everything that happens in the universe.

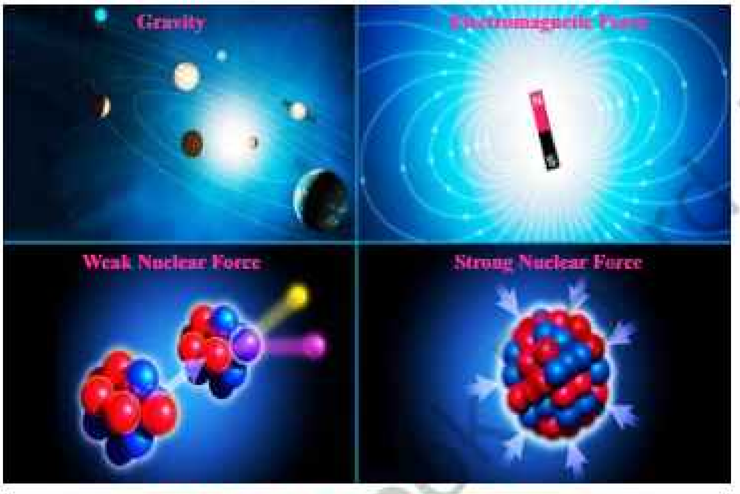


Fig: 16.1 Fundamental forces of nature

Gravity is the force that attracts matter across long distances (tens of millions of light years). The electromagnetic force is extremely powerful, but it operates at very small scales, forcing positively charged atomic nuclei to attract negatively charged electrons, resulting in the formation of atoms and molecules.

It's the fundamental reason that electrons are hold by nucleus and are accountable for the nucleus entire structure.

Electromagnetism serves as a basic principle of working for many of the home appliances in household applications. These applications include lighting, air conditioning systems, Generators, transformers etc. Students will be able to understand all the above facts after completing this unit.

Do You Know!

Electromagnetic force in forming matter

Coulombs' Law

Like charges repel, unlike charges attract. Protons repel each other and the same is true for electrons, but the electromagnetic force attracts electrons to protons.

Electron Capture

The electromagnetic force pulls electrons into orbit around positively charged atomic nuclei. The larger the nuclei, the more electrons are pulled in.

Atoms and molecules

The electromagnetic force holds atoms and molecules together. Electrons occupy energy levels around atomic nuclei balancing out positive and negative charges

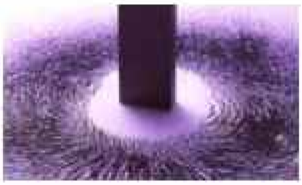


Fig: 16.2
Electromagnetic force

Do You Know!

The electromagnetic force, also called the Lorentz force, acts between charged particles, like negatively charged electrons and positively charged protons. Opposite charges attract one another, while like charges repel. The greater the charge, the greater the force.

Electromagnetic force

The electromagnetic force, as its name suggests, is consist of two forces, electric and magnetic forces. Physicists once thought of these forces as independent entities, but eventually discovered that they are parts of the same force.

The electric charge interacts with charged particles, whether they're moving or stationary, to create a field in which the charges can influence one another. When those charged particles are set in motion, however, they begin to exhibit the second component, magnetic force. As the charged particle start to move, they produce a magnetic field surrounding them as illustrated in figure 16.3. As a result, when electrons flow across a wire to charge your computer or phone, or switch ON your TV, the weak magnetic field produced around the wire.

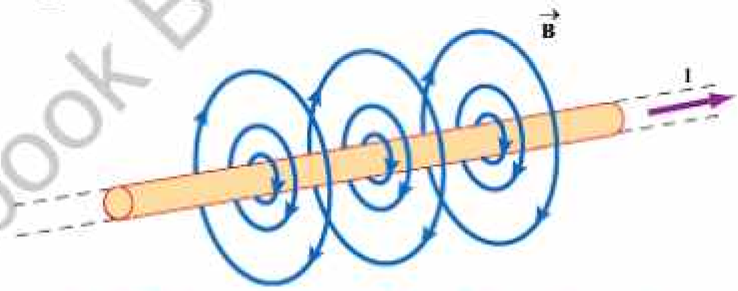


Fig: 16.3 Connection between electricity and magnetism

16.1 Magnetic effect of a steady current

You can demonstrate the magnetic field around the current-carrying conductor by doing an experiment. Pass a current-carrying conductor through a cardboard sheet. Small compasses should be placed near the conductor. Figure 16.4 shows how the compasses will point in the direction of the magnetic lines of force.

The magnetic field direction around a current-carrying conductor can be determined using the Flemings right hand rule for conductors.

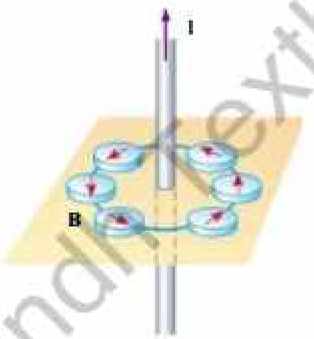


Fig: 16.4 Compasses align to reveal a circular magnetic field pattern around a current-carrying conductor.

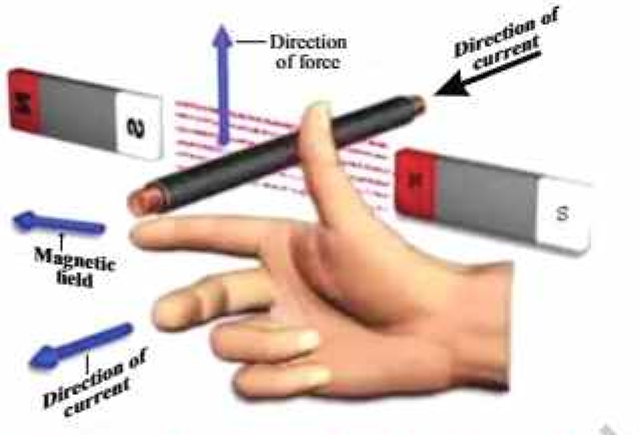


Fig: 16.5 Demonstration of the right-hand rule for conductors.

Do You Know!

When current flowing upward direction its indicated the north pole and downward direction is south pole.

Consider the dot in the middle of the conductor on the left as the point of an arrow in Figure 16.6. This indicates that an electric current is traveling in your direction. The magnetic field's direction is indicated by circular arrows. When electrical wires carry alternating currents, this principle is important. This is due to the fact that the positioning of wires, known as lead dress, has an impact on the operation of a circuit.

When possible, conductors are grouped in pairs to reduce heating and radio interference caused by the magnetic field created by electric current flow. To help reduce this heating effect, the National Electric Code requires that wires be run in pairs.

These conventions are used to show the link between electric current flow and the magnetic field. The dot represents a current arrow heading toward you. The cross on the right represents the tail end of the current arrow heading away from you.

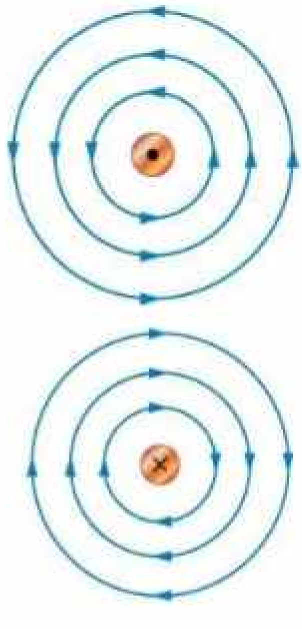


Fig: 16.6
Magnetic field produced by current

Magnetic field produced by current carrying conductor

When electric charges are at rest, they exert electrostatic forces of attraction or repulsion on each other. As we know that isolated moving charges produce both electric and magnetic fields, but an electric current through a conductor produces only a magnetic field because the electric field of moving electrons is neutralized by the field of the fixed protons in the conductor. The magnetic field around a magnetic moving charge is a vector quantity symbolized by B.

Now suppose a particle carrying charge q is projected with speed v into a magnetic field of magnetic induction B such that the angle between B and V is θ. The magnetic field of the charged particle interacts with the magnetic field of the magnet in which it is sent, due to which a force is produced which acts upon the particle. It is found that:

- The force F acting on the particle is directly proportional to the charge q.
- The force F acting on the particle is directly proportional to the velocity V.
- The force F is directed perpendicular to the plane containing V and B.

Combining the above three observations, we found that:

$F = q\,V \times B$

So the magnitude of B is given by:

$$B = \frac{F}{qV \sin\theta} = \frac{\text{Newton}}{\text{Coulmb} \times \text{m/sec}} = \frac{\text{Newton}}{\text{Ampere x meter}} = 1 \text{ Tesla}$$

It is called 1 Tesla.

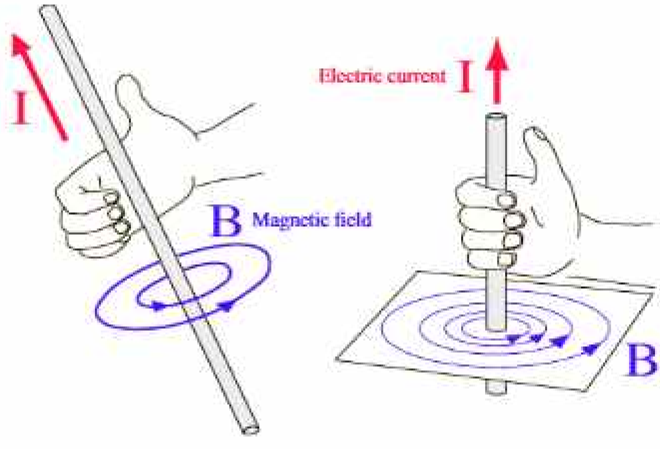


Fig: 16.7 Current carrying conductor produce magnetic field

Do You Know!

Tesla is a unit of magnetic flux density in the MKS system it is equivalent to one weber per square meter.

$1\,\text{Tesla} = 10^4\,\text{Gauss}$

Weblinks

Encourage students to visit below link for Magnetic field due to a current carrying conductor

https://www.youtube.com/watch?v=5fY74-v96N0&ab_channel=Learnnhvfun

SELF ASSESSMENT QUESTIONS:

Q1: Why the workdone on a charge is zero by magnetic force?

Q2: If two wire placed parallel, when current following in same direction, what will be happen?

Q3: What is the angle between $\vec{E}$ and $\vec{B}$ in a electromagnetic wave?

Define Magnetic field

The magnetic field is the region in which the influence of magnetism may be felt in the region of a magnet, and it is defined as follows: When we talk about magnetic fields in nature, we're talking about how the magnetic force is diffused throughout the space surrounding and inside magnetic objects in the physical world.

Sketch the lines of magnetic force.

In general, the magnetic field is the strongest near the poles, and the weakest at the centre.

Magnet field lines

Magnetic field lines are imaginary lines coming outward from the north pole and going inward in a south pole and inside a bar magnet magnetic field will be zero. The magnetic field is stronger at the end of pole because magnetic field lines are very closer at end of poles.

To understand magnetic field lets preform an activity,

Take a bar magnet and hundreds of iron filings; place the bar magnet on a table and sprinkle the iron filings on it; the iron filings will self-organize into curving lines called magnetic field lines, as seen in the figure

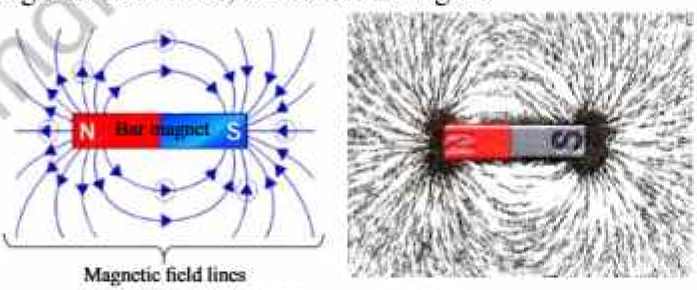
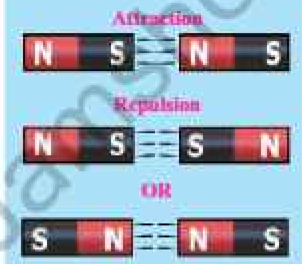


Fig: 16.8. Magnetic field lines

Do You Know!

Like poles repel one another, whereas unlike poles attract one another.



Do You Know!

Earth has magnetic field around it , because of flowing of liquid metal in the outer core cause to generates electric currents., it protected from the solar wind, a stream of energetic charged particles emanating from the Sun, by its magnetic field, which deflects most of the charged particles. The earth magnetic field is $50\mu T$.

Do You Know!

Beautiful coloured lightening happened in north and south pole because the shape of Earth's magnetic field creates two aurora above the North and South Magnetic Poles.

SELF ASSESSMENT QUESTIONS:

Q1: Are magnetic lines of force real?

Q2: What is the source of the magnetic field?

Q3: What are the magnetic lines of force?

Q4: What is the direction of magnetic field inside the bar magnet?

Q5: Can monopole of magnet exist?

16.2 Force on current carrying conductor in a magnetic field

When a conductor of length L carrying current, I and placed in a magnetic field B at an angle θ as shown in figure16.9, it experiences aforce:

$$F = I(l \times B)$$

$$F = BIL \sin\theta$$

$$B = \frac{F}{IL \sin\theta}$$

We know that current in a conductor is due to the directional drift of free electrons along the conductor so when a conductor is placed in a uniform magnetic field B and if the current, I is passed, the conductor experiences a force as mentioned above.

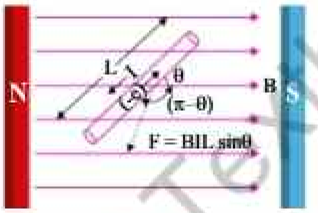


Fig: 16.9
Current carrying conductor in magnetic field

When a conductor carries an electric current, a magnetic field is produced around it.

OR

It exhibits magnetic properties and generates a force when another magnet is brought into its magnetic field. In the same way.

The magnetic field has an equal and opposite effect on the conductor carrying the current. This is because two magnetic fields (from the current-carrying conductor and the nearby magnet) can attract or repel each other. The direction of the external magnetic field and the direction of the current in the conductor are responsible for this attractive and repulsive forces. The direction of the force acting on the conductor will be perpendicular to the direction of the magnetic field and the electric current if they are perpendicular to each other.

Worked Example 1

Calculate the force on the wire shown in Figure (a)

Solution

Step 1: Write down the known quantities and quantities to be found.

$B = 1.50T$

$l = 5.00$ cm

$I = 20A$

$\theta = 90°$

$F = ?$

Step 2: Write down the formula and rearrange if necessary.

$F = IlB\sin\theta$

Step 3: Put the values and calculate

$F = IlB\sin\theta$

$F = IlB \sin\theta = (20A)(0.0500\ m)(1.50\ T)(1).$

The units for tesla are $1\ \frac{N}{Am} = T \rightarrow N = AmT$

$F = 1.50\ N$

Result: The force on a wire is $F = 1.50$ N.

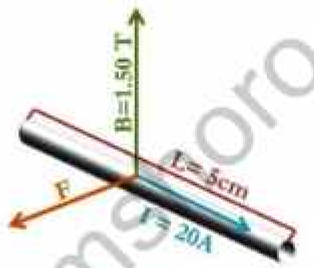


Fig: (a)

16.3 Turning effect on a current-carrying coil in a magnetic field

When a current passes through the coil, equal and opposite parallel forces act respectively on the sides of the coil beside the poles of the permanent magnet. This pair of forces produces a turning effect to rotate the coil until it is stopped by the control springs.

A current-carrying coil kept in a magnetic field experiences a torque, which is the cross-product of the magnetic moment and the field vector. Hence, the torque is maximum when the dipole moment is perpendicular to the field, and zero when it's parallel or antiparallel to the field.

When an electric current is passed through a coil, placed in a magnetic field with its plane parallel to the field, it experiences a torque. Thus, this rectangular coil tends to rotate in the magnetic field and it suffers torque. This torque is:

$$\tau = BIAN \cos\alpha$$

Consider a rectangular coil placed in the magnetic field of

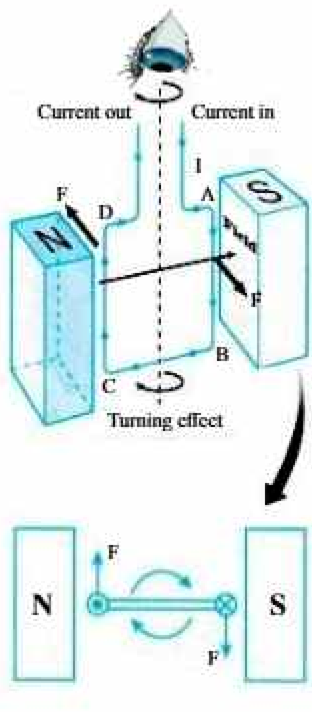


Fig: 16.10
Torque on coil current carrying conductor

Do You Know!

Invention of D.C motor

William Sturgeon invented the first D.C motor, that could provide enough power to drive machinery but it wasn't until 1886 that the first practical D.C motor that could run at constant speed under variable weight, was produced. Frank Julian Sprague was its inventor and it was this motor that provided the catalyst for the wider adoption of electric motors in industrial applications.

strength B and the plane of the coil is parallel to the field and is free to rotate about an axis.

When current I passed through the coil, a force is experienced on the perpendicularly placed conductor. The magnitude of the force is $F = BIL$. Hence a pair of two equal but opposite forces (couple) acts on the coil. That causes the coil to rotate.

So, Torque = $\tau = BIA$

If the plane of the coil makes an angle α with the field B then the perpendicular distance $\cos\alpha$ can be added:

$$\tau = BIA\cos\alpha$$

If the coil has N turns, then:

$$\tau = BIAN\cos\alpha$$

16.4 D.C motor

D.C Motor is an Electromechanical device that converts electrical energy into mechanical energy. D.C Motor is similar to D.C Generator in construction but the output device act as input and input as output.

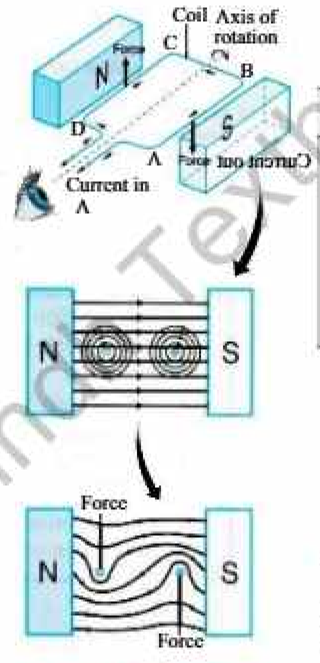


Fig: 16.12 Torque on D.C motor

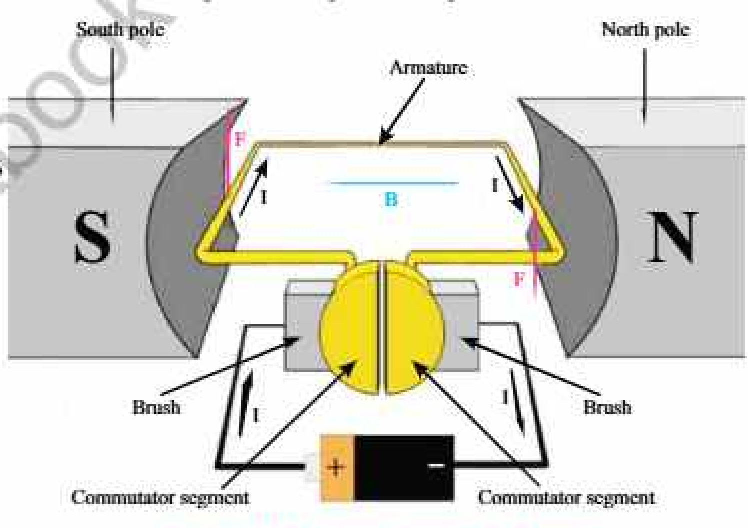


Fig: 16.11. Turning effect on D.C motor

Turning effect on D.C motor coil

A current-carrying coil in a magnetic field experiences a turning effect. In Figure 16.12, a rectangular coil ABCD carries a current in the magnetic field between two magnets.

(a) The sides BC and DA carry currents with directions parallel to the magnetic field. No force is exerted on thesetwo sides.
(b) The side AB next to the South pole experiences a force. The direction of the force can be determined using Flemings left -hand rule or the right-hand slap rule.
(c) The side CD experiences a force that acts in the opposite direction.

The two forces acting in opposite directions on the two sides of the coil form a couple and produce a turning effect on the coil. The forces are produced when the magnetic field due to the current in the coil combines with the external magnetic field to produce two resultant catapult fields around the coil; Figure 16.13.

Two important applications of the turning effect of a current-carrying coil in a magnetic field are the direct current motor and the moving-coil galvanometer.

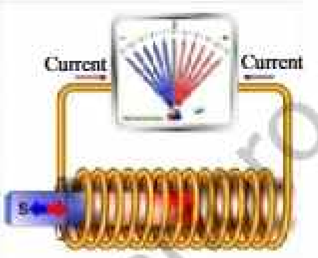


Fig: 16.13 Electromagnetic induction

SELF ASSESSMENT QUESTIONS:

Q1: How can the turning effect of a coil be increased?

Q2: How do DC motor coils rotate?

16.5 Electromagnetic induction

A voltage is created – or induced. For this reason, we call this electromagnetic induction. Electromagnetic or magnetic induction is the production of an electromotive force across an electrical conductor in a changing magnetic field. Michael Faraday is generally credited with the discovery of induction in 1831, and James Clerk Maxwell described mathematically it as Faraday's law of induction.

Changing magnetic field can induce e.m.f in a circuit.

Faraday demonstrates that magnetic fields can create currents as illustrated in figure 16.14. When the magnet shown below is moved "towards" the coil, the Galvanometer's pointer or needle will deflect away from its centre position in one direction only. When the magnet stops moving and is held stationary with respect to the

Do You Know!

Concept of electromagnetic induction given by **"Joseph henry"** in 1830,from USA

"Michael Faraday" from England also gave the concept of electromagnetic induction and in 1831.

coil, the needle of the galvanometer returns to zero as there is no physical movement of the magnetic field.

Similarly, when the magnet is moved "away" from the coil, the galvanometer needle deflects in the opposite direction, indicating a change in polarity. By moving the magnet back and forth towards the coil, the needle of the galvanometer will deflect left or right, positive or negative, relative to the magnet's motion.

Weblinks

Encourage students to visit below link for Electromagnetic induction and Faraday's law

https://www.youtube.com/watch?v=3HyORmBip-w&ab_channel=IkenEdu

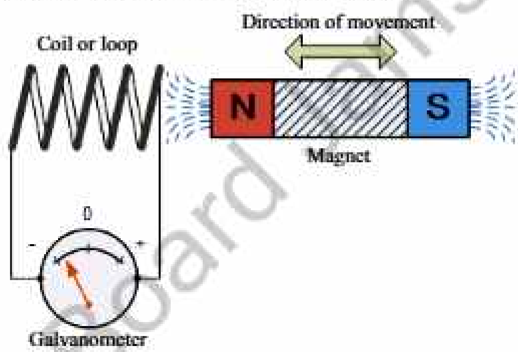


Fig: 16.14 changing magnetic produced induced e.m.f

Electromagnetic Induction by a Moving Magnet

if you keep the magnet stationary and move only the coil toward or away from the magnet, the needle on the galvanometer will also move in either direction. A voltage is induced in a coil when the coil is moved through a magnetic field, and the magnitude of this voltage is proportional to the speed at which the coil is moved.

For Faraday's law to be valid, either the coil or the magnetic field (or both) must be in "relative motion" with one another for the induced emf or voltage to be increased with increasing field speed.

Weblinks

Encourage students to visit below link for Faraday's law of induction

https://www.youtube.com/watch?v=vcStzn5MG0&ab_channel=KhanAcadem

Faraday's Law of Induction

From the above description we can say that a relationship exists between an electrical voltage and a changing magnetic field to which Michael Faraday's famous law of electromagnetic induction states:

A voltage is induced in a circuit whenever relative motion exists between a conductor and a magnetic field and that the magnitude of this voltage is proportional to the rate of change of the flux".

Factors affecting the magnitude of an induced e.m.f.

The factors involved in the induced emf of a coil are:

- The induced e.m.f. is directly proportional to N, the total number of turns in the coil.
- The induced e.m.f. is directly proportional to A, the area of cross-section of the coil.
- The induced e.m.f. is directly proportional to B, the strength of the magnetic field in which the coil is rotating.
- The induced e.m.f. is directly proportional to 'ω', the angular velocity of the coil.
- The induced e.m.f. also varies with time and depends on instant 't'.
- The induced e.m.f. is maximum when the plane of the coil is parallel to magnetic field B and e.m.f. is zero when the plane of the coil is perpendicular to magnetic field B.

Lenz's law of electromagnetic induction

According to Faraday's law of electromagnetic induction, a changing magnetic field induces a current in a conductor. Lenz's law of electromagnetic induction states that the magnetic field produced by the induced current opposes the original magnetic field that produced the current. The right hand rule, developed by Fleming, specifies the direction of this current's flow.

Keep in mind that the magnetic field produced by an induced current generates an additional magnetic field, which a Always opposing the magnetic field that formed it. Below illustration showing that, if magnetic field "B" is increasing, the induced magnetic field will oppose it in figure 16.15(a).

As illustrated in 16.15(b), the induced magnetic field will once again oppose the magnetic field "B" when "B" is decreasing. This time, "in opposition" suggests it's acting to increase the field by opposing the decreasing rate of change.

Lenz's law derives from Faraday's law of induction. According to Faraday's law, a conductor will experience an electric current when subjected to a changing magnetic

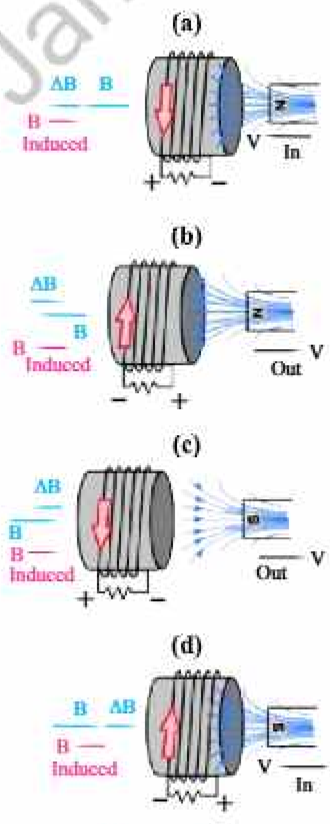


Fig: 16.15 Magnetic field induced by magnetic current

field.

When a magnetic field changes, an induced current will flow in the opposite direction, as described by Lenz's law. That's why the minus sign ('-') appears in the formula for Faraday's law to emphasize this point.

It is possible to alter the magnetic field intensity by moving a magnet closer to or farther from the coil, or by moving the coil itself into or out of the magnetic field.

In other words, we can say that the magnitude of the EMF induced in the circuit is proportional to the rate of change of flux.

$$\mathcal{E} \propto -\frac{d\Phi_B}{dt}$$

$$\mathcal{E} = -N\frac{d\Phi_B}{dt}$$

Where:

- $\mathcal{E}$ = Induced emf
- $d\Phi_B$ = change in magnetic flux
- N = No of turns in coil

Weblinks

Encourage students to visit below link for Lenz's Law and Conservation of Energy

https://www.youtube.com/watch?v=wsuBld3Bo00&ab_channel=YenLingLam

Lenz's Law and Conservation of Energy

To obey the law of energy conservation, the direction of the current induced by Lenz's law must create a magnetic field that is opposite to the magnetic field that created it. In fact, Lenz's law is a result of the law of conservation of energy.

If the magnetic field created by the induced current is in the same direction as the field that produced it, then the two magnetic fields would combine to make a larger magnetic field.

By combining their magnetic fields, they may create a field that is twice as strong as the original one, inducing a current twice as large in the conductor.

As a result, a new magnetic field would be produced, which in turn would induce a new current. And so on.

Because of this, it is easy to understand that the conservation of energy would be violated if Lenz's law did not state that the induced current must produce a magnetic field that opposes the field that originated it.

Do You Know!

Lenz's law is about the conservation of energy applied to the electromagnetic induction, whereas Faraday's law is about the electromagnetic force produced.

The third law of motion of Newton applies to Lenz's law as well (i.e to every action there is always an equal and opposite reaction).

If the induced current makes a magnetic field in the same direction as the magnetic field that made it, then it is the only thing that can stop the change in the magnetic field in the area. This is consistent with Newton's third law of motion.

16.6 A.C generator

An AC generator is an electric generator that converts mechanical energy into electrical energy in the form of alternative emf or alternating current. An AC generator works on the principle of "Electromagnetic Induction".

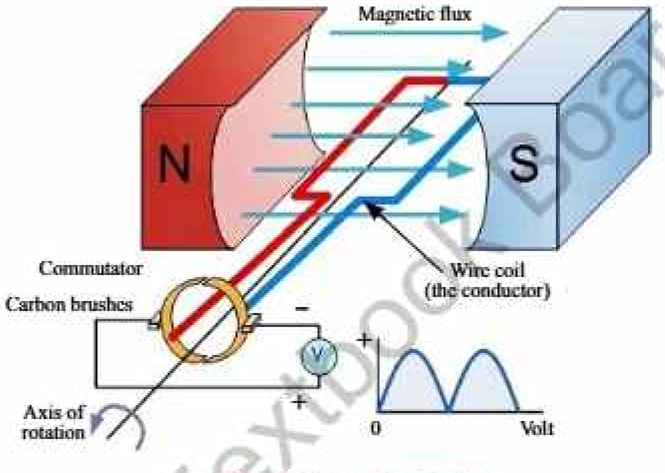


Fig: 16.16 A.C generator

Do You Know!

The S.I unit of mutal inductance is "**Henry**" while is equal to $\frac{\text{Volt}-\text{Sec}}{\text{Amp}}$

16.7 Mutual induction

When the electric current in the Primary Coil changes, the magnetic field changes as well, linking the Secondary Coil to the Primary Coil. In the secondary coil, this shifting flux causes an e.m.f. Mutual Induction describes this process. The secondary coil's e.m.f. is proportional to the primary coil's rate of change of current. Thus:

$$\varepsilon_s \propto \frac{\Delta I_p}{\Delta t}$$

$$\varepsilon_s = -M \frac{\Delta I_p}{\Delta t}$$

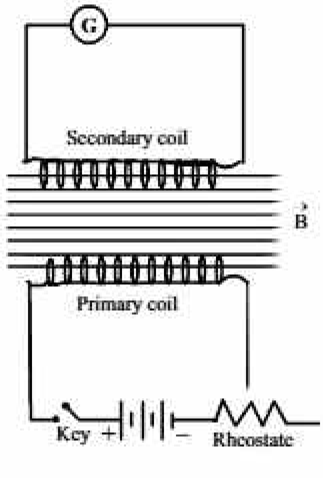


Fig: 16.17
Mutual induction

Where M is a constant, called Mutual Inductance of the two coils.

Hence:

$$M_s = \frac{\varepsilon_s}{\Delta I_p / \Delta t}$$

SELF ASSESSMENT QUESTIONS:

Q1: Define mutual induction.

Q2: Enlist the factors affecting the induced e.m.f.

Q3: How A.C generator works?

Do You Know!

- Stabilizer is the example of step up transformer
- Mobile charger is the example of step down transformer
- Working principle of transformer based upon mutual induction

16.8 Transformer

Transformer is a static machine used for transforming power from one circuit to another without changing the frequency. Transformers operate based on the principle of **mutual induction**. It operates on an AC supply.

It consists of two coil which are magnetically linked to each other but electrically isolated from one another although wrapped around the same iron core, make up a transformer. The primary coil is the first of two coils in the system which is connected to A.C input power. The secondary coil is the other coil which delivers the power to the output circuit. N_P and N_S stand for the number of turns on the primary and secondary coils, respectively.

When current passing through the primary coil generates magnetic field, which is transmitted to the secondary coil through the core. The change in the field causes an alternating e.m.f. to be generated in the secondary coil.

The secondary voltage V_S is proportional to the primary voltage V_P. The ratio of the number of turns on the secondary coil to the number of turns on the main coil also affects the secondary voltage, as illustrated by the following expression:

$$\frac{V_S}{V_P} = \frac{N_S}{N_P}$$

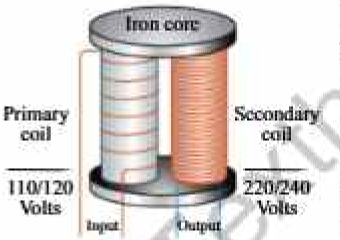


Fig: 16.18 (a)
Step up transformer

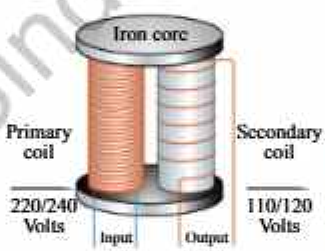


Fig: 16.18 (b)
Step down transformer

The transformer is referred to as a step-up transformer if the secondary voltage exceeds the primary voltage; Fig.16.18 (a).

A step-down transformer is one in which the secondary voltage is lower than the primary voltage; Fig.16.18 (b).

The electric power transferred to the secondary circuit in an ideal transformer is the same as the primary circuit's power.

An ideal transformer dissipates no power, and we may write the following mathematical expression for such a transformer

$$P_P = P_S$$
$$V_P I_P = V_S I_S$$

Weblinks

Encourage students to visit below link for How does a transformer works

https://www.youtube.com/watch?v=UchitHGF4n8&ab_channel=TheEngineeringMindset

Role of Transformer in Power Transmission

Generation of electrical power in low voltage level is very much cost effective. Theoretically, this low voltage level power can be transmitted to the receiving end. This low voltage power if transmitted results in greater line current which indeed causes more line losses.

But if the voltage level of a power is increased, the current of the power is reduced which causes reduction in ohmic or $P = I^2R$ losses in the system, reduction in cross-sectional area of the conductor i.e. reduction in capital cost of the system and it also improves the voltage regulation of the system. Because of these, low level power must be stepped up for efficient electrical power transmission.

This is done by step up transformer at the sending side of the power system network. As this high voltage power may not be distributed to the consumers directly, this must be stepped down to the desired level at the receiving end with the help of step down transformer. Electrical power transformer thus plays a vital role in power transmission.

Weblinks

Encourage students to visit below link for Role of transformer in power transmission

https://www.youtube.com/watch?v=agujzHdvtjc&ab_channel=PhysicsVideosbyEugeneKhutoryansky

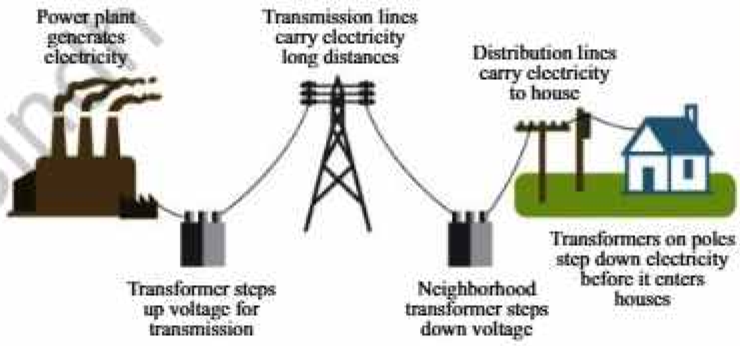


Fig: 16.19
Power transmission from power house to residential area

Fig: 16.20
Transformer in stabillizar

Fig: 16.21
Transformer battery charger

Fig: 16.22
Transformer in high voltage circuit breaker

Daily life applications of transformers

Transformers are widely used because of their ability to regulate the strength of alternating current, which improves efficiency and, in turn, reduces monthly electricity costs. By the use of transformers, we have observed and seen its importance in our everyday life and without it, electricity would have caused great destruction in our homes and industries.

There are several ways a transformer can be used in homes.

In stabilizer:

A stabilizer is made up of transformers that help to give out a voltage or manage voltage in such a way that it is ok with the voltage circuits. It helps to step down and step up the level of current in a building.

In Battery Charger:

Batteries can also be charged with the help of transformers. The voltage needs to be controlled properly so that it doesn't damage the parts inside the battery. This can only be done with the help of a step down transformer.

In circuit breaker:

Circuit breakers with integrated transformers can prevent damage from high voltage current by allowing users to manually switch on and off power.

In air conditioner (AC):

This is another modern use of a transformer in our homes. Because of its high inductance and low resistance levels, it aids in the proper functioning of the AC. Without this, there would be no long-lasting AC (Air condition) in our home.

SELF ASSESSMENT QUESTIONS:

Q1: What is transformer and how its works?

Q2: What is the difference between step up and step down transformer?

Q3: For what purpose step up and step down transformers are used in power transmission?

SUMMARY

- Electromagntic force acts between charged particles.
- The direction of magnetic field around a current carrying wire can be determined by using the Flemings right hand rule for conductors.
- The region in which the influence of magnetism may be felt is known as magnetic field.
- Magnetic field is strongest near the poles and weakest in the centre.
- A current carrying wire has a magnetic field around it. When this field interacts with external magnetic field there is a force on it, which is given by $F = I\,L \times B$.
- DC motor is a device which converts the electrical energy into mechanical energy.
- Faraday noticed that when he moved a permanent magnet in and out of a coil or a single loop of wire it induced an Electro Motive Force or emf, in other words a Voltage, and therefore a current was produced.
- Torque on a current carrying coil in magnetic field is $\tau = NIAB\sin\theta$.
- The change of magnetic flux due to a variation in the current flowing in another circuit.
- Dynamically induced e.m.f: When the conductor is moved in a stationary magnetic field in such a way that the flux linking it changes in magnitude.
- Statically induced e.m.f: When the conductor is stationary and the magnetic field is moving or changing.
- Eddy currents: The currents induced in conductor moving in a magnetic field or metals that are exposed to a changing magnetic field.
- Generator is an electrical machine which converts mechanical energy into electrical energy.
- Electrical transformer plays vital role in power transformation. In addition, transformers can be used to scale up or down an alternating voltage's intensity. It works on the idea of mutual induction.

CONCEPT MAP

Electromagnetism

The branch of Physics which deals with magnetic effects of electric current

- Magnetic field due to current in a long straight wire
- Force on a current carrying conductor in uniform magnetic field $F = BIL \sin\alpha$
- Magnetic induction (Unit tesla)
  - AC generator
- Mutual Induction
  - Step up
  - Step down
- Torque on a current carrying coil $\tau = IBA \cos\alpha$

Section (A) Multiple Choice Questions (MCQs)

1. Which statement is true about the magnetic poles?
   (a) unlike poles repel
   (b) like poles attract
   (c) magnetic poles do not effect each other
   (d) a single magnetic pole does not exist
2. What is the direction of the magnetic field lines inside a bar magnet?
   (a) from north pole to south pole (b) from south pole to north pole
   (c) from side to side (d) there are no magnetic field lines
3. The presence of a magnetic field can be detected by a
   (a) small mass (b) stationary positive charge
   (c) stationary negative charge (d) magnetic compass
4. If the current in a wire which is placed perpendicular to a magnetic field increases, the force on the wire
   (a) Increases (b) decreases
   (c) remains the same (d) will be zero
5. A D.C motor converts
   (a) mechanical energy into electrical energy
   (b) mechanical energy into chemical energy
   (c) electrical energy into mechanical energy
   (d) electrical energy into chemical energy
6. Which part of a D.C motor reverses the direction of current through the coil every half-cycle?
   (a) the armature (b) the commutator
   (c) the brushes (d) the slip rings
7. The direction of induced e.m.f. in a circuit is in accordance with conservation of
   (a) Mass (b) charge (c) momentum (d) energy
8. The step-up transformer
   (a) increases the input current
   (b) increases the input voltage
   (c) has more turns in the primary
   (d) has less turns in the secondary coil
9. The turn ratios of a transformer is10. It means
   (a) $I_S = 10\, I_p$ (b) $N_p = 10 N_S$
   (c) $N_S = 10\, N_p$ (d) $V_S = 10 V_p$

Section (B) Structured Questions

1. A wire in a magnetic field generates voltage. To generate maximum voltage, move the wire in what direction relative to the field?
2. Can a transformer operate on direct current?
3. Demonstrate through an experiment how an electric current in a conductor generates a magnetic field in its vicinity.
4. Explain how a force works on a current-carrying conductor that is perpendicular to the magnetic field.
5. State that, a current carrying coil in a magnetic field will experience a torque.
6. Describe an experiment that demonstrates the induction of e.m.f. in a circuit by a varying magnetic field.
7. Give some examples of what could increase or decrease the strength of an induced e.m.f.
8. Explain that the direction of an induced e.m.f opposes the change causing it and relate this phenomenon to conservation of energy.
9. Explain how an A.C. generator works in its most simple form.
10. Explain the units of mutual induction and provide an example.
11. Recognize that a transformer is based on the concept of mutual induction between two coils.
12. Explain what role transformers play in alternating current (AC) circuits.
13. Determine the function of transformers in the process of moving electrical current from the power plant to your home.
14. Compile a list of the numerous applications of transformers (step-up and step-down) that can be found in your home.

Section (C) Numericals

1. A wire carrying 4A current and has length of 15 cm between the poles of a magnet is kept at an angle of 30^{o} to the uniform field of 0.8 T. Find the force acting on the wire? **(0.24N)**
2. A square loop of wire of side 2.0 cm carries 2.0 A of current. A uniform magnetic field of magnitude 0.7 T makes an angle of 30^{o} with the plane of the loop. What is the magnitude of torque on the loop? **($4.8\text{x}10^{-4}$ Nm)**
3. A transformer is needed to convert a mains 220 V supply into a 12 V supply. If there are 2200 turns on the primary coil, then find the number of turns on the secondary coil. **(120)**
4. A coil surrounding a long solenoid, the current in the solenoid is changing at a rate of 150A/s and the mutual induction of the two coils is 5.5×10^{-5}H. Determine the emf induced in the surrounding coil? **(-8.25×10^{-3}V).**

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