Chapter = 16

Electromagnetism

Q1.Define Electromagnetism, Electromagnetic force.

Electromagnetism

Electromagnetism is a branch of Physics that deals with the electromagnetic force that occurs between electrically charged particles.

Electromagnetic force

The electromagnetic force is a type of physical interaction that occurs between electrically charged particles.

Q2.Discus the Magnetic field of a study current

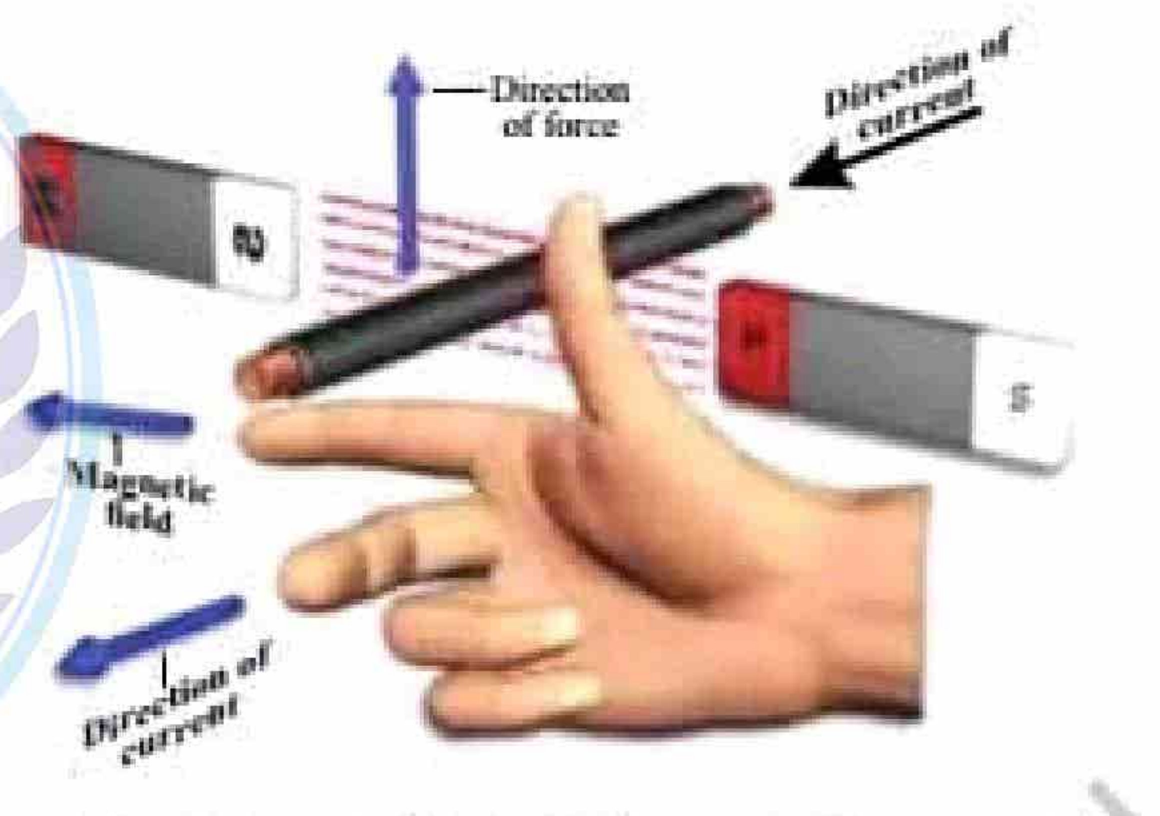
Magnetic field of a study current

Pass a current-carrying conductor through a cardboard sheet. Small compasses should be placed near the conductor. Then, the compasses will point in the direction of the magnetic lines of force.

Rule

The magnetic field direction around a current carrying conductor can be determined by following this rule.

"The magnetic field made by a current in a straight wire curl around the wire in a ring. You can find it by pointing your right thumb in the direction of the current in the wire and curling your fingers. Your fingers will be curled in the same direction as the magnetic field around the wire".



Demonstration of the right-hand rule for conductors.

Q3.What is Fleming's right hand rule

Fleming's right hand rule Fleming's right-hand rule gives which direction the current flows.

The right hand is held with the thumb, first finger and second finger mutually perpendicular to each other (at right angles), as shown in the diagram.

- The thumb is pointed in the direction of force.
- The first finger is pointed in the direction of the magnetic field. By convention, it is directed from the North to South magnetic pole.
- Then the second finger represents the direction of the induced or generated current within the conductor.

Q4.Derive a formula for Force acting on a charge moving through a magnetic field

Force acting on a charge moving through a magnetic field

Now suppose a particle carrying charge **q** is projected with speed **V** into a magnetic field of 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 x B)

So the magnitude of B is given by:

$$B = \frac{F}{qvSin\theta}$$

Define Magnetic field and Magnetic field lines

Magnetic field

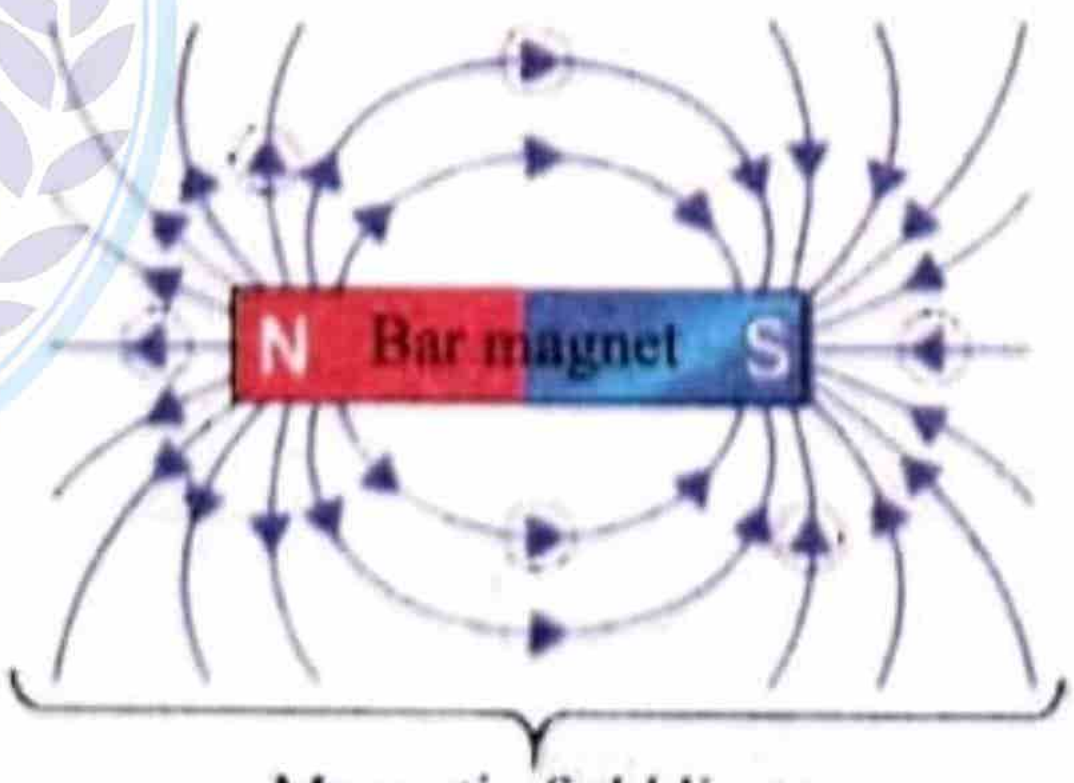
Magnetic Field is the region around a magnetic material or a moving electric charge within which the force of magnetism acts.

Example

Earth has magnetic field around it, because of flowing of liquid metal in the outer core cause to generate electric current.

Magnetic 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 strongest at the end of the pole because magnetic field lines are very close at the end of poles, while it is weakest at the centre.



Magnetic field lines

Q5.Define Magnetic flux density. Also give is unit.

Magnetic flux density or magnetic induction

Definition: A vector quantity measuring the strength and direction of the magnetic field around a magnet or an electric current.

Representation: It is represented by B.

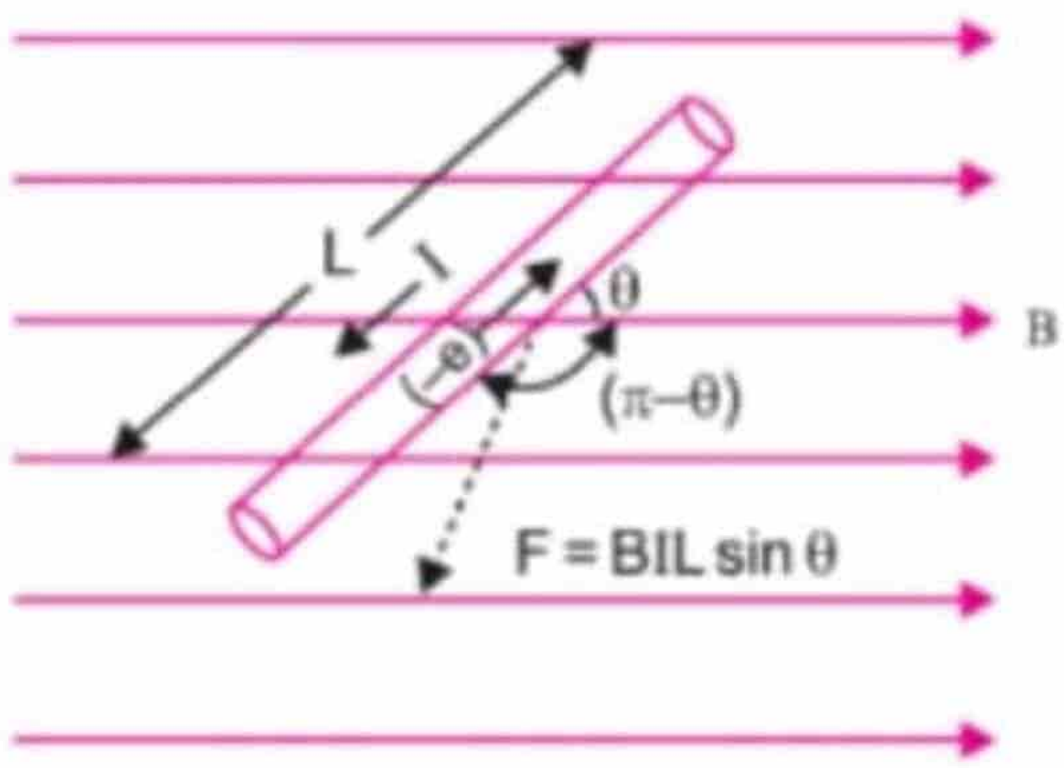
Unit: Its unit is tesla (N/(A x m)).

Q6.Derive an expression for Force on current carrying conductor in a magnetic field

Force on current carrying conductor in a magnetic field

When current passes through a conductor placed in a magnetic field experiences a force.

When a conductor of length **L** carrying current **I** and placed in a magnetic field **B** at an angle **θ** as shown in figure, it experiences a force **F**:



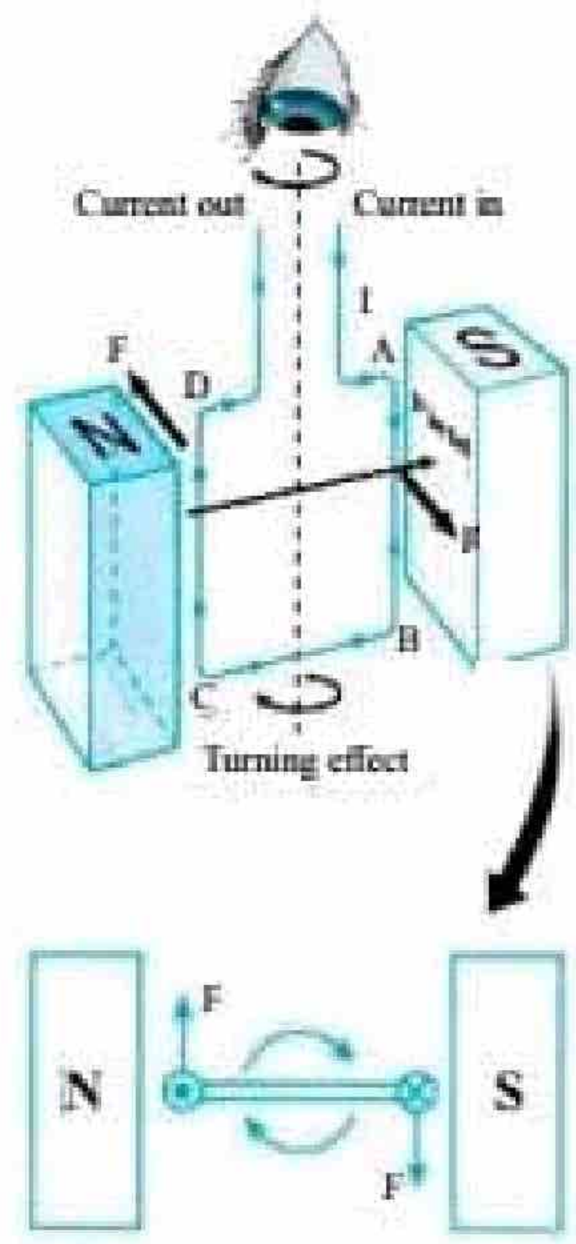
$$F = I\,(l \times B)$$
$$F = BIL\,sin\theta$$
$$B = \frac{F}{Il sin\theta}$$

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.

Q7.Derive an expression for Turning effect on a current carrying coil in a magnetic field.

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 supported by the control springs.



Consider a rectangular coil placed in the magnetic field of strength **B** and the plane of the coil is parallel to the field and is free to rotate about an axis. When current **I** passes 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,

$$\text{Torque} = \tau = BIA$$

If the plane of the coil makes an angle **α** with the field **B** then the perpendicular distance **Cosα** can be added:

$$\tau = BIA\,Cos\alpha$$

If the coil has N turns, then:

t = BIAN Cos

Q8. What is D.C motor. Describe the construction and working of D.C motor. Also draw its figure

D.C motor

D.C motor is an electromechanical device that converts electrical energy into mechanical energy.

Construction

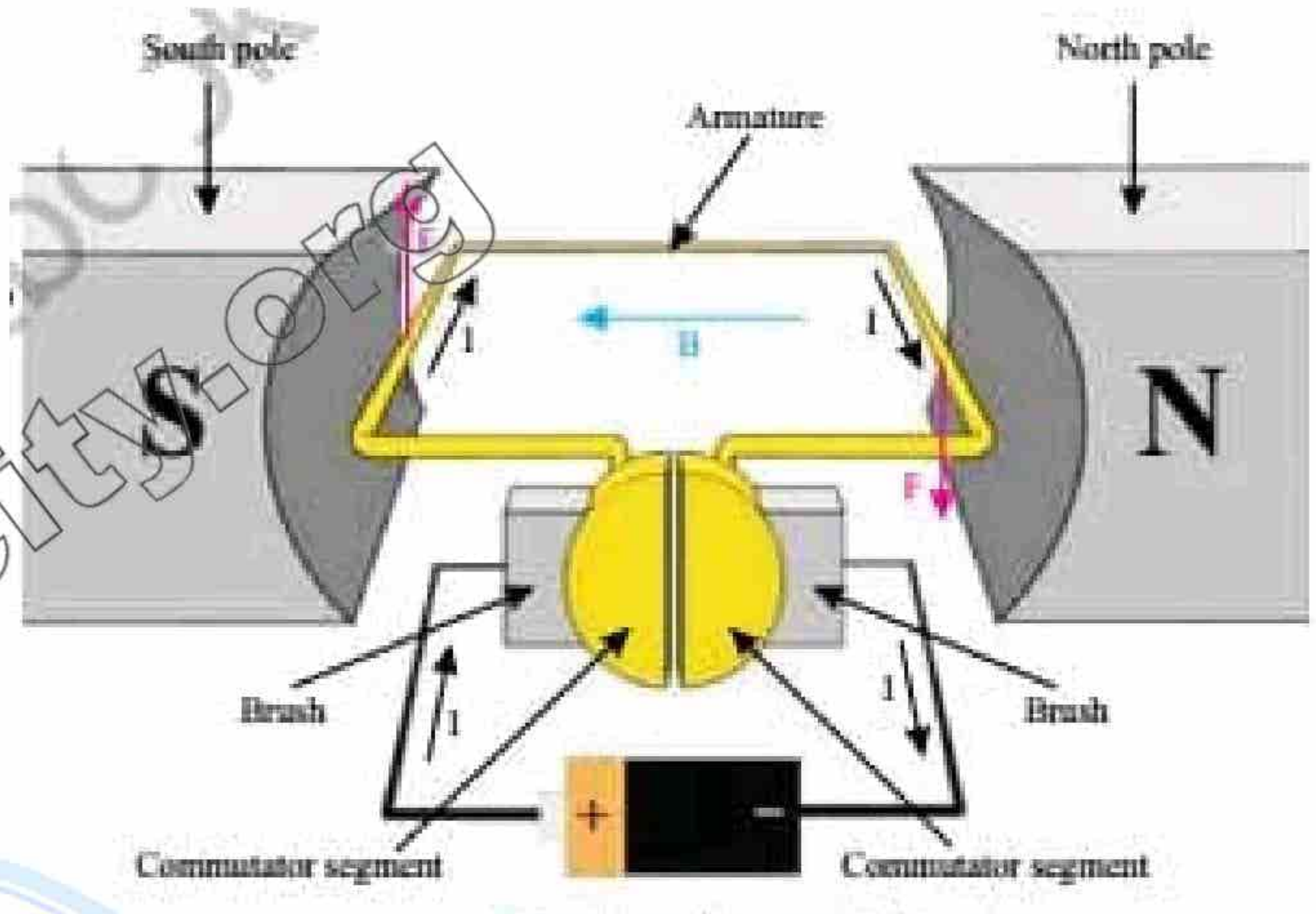
A D.C motor consists of following main parts.

Magnetic Field System

The magnetic field system of a D.C motor is the stationary part of the machine. It produces magnetic field in the motor.

Armature

The armature of D.C motor is connected with the shaft and rotates between the field poles after passing current through it.



Turning effect on D.C motor

Commutator

A commutator is a mechanical rectifier which converts the direct current input to the motor from the DC source into alternating current in the armature.

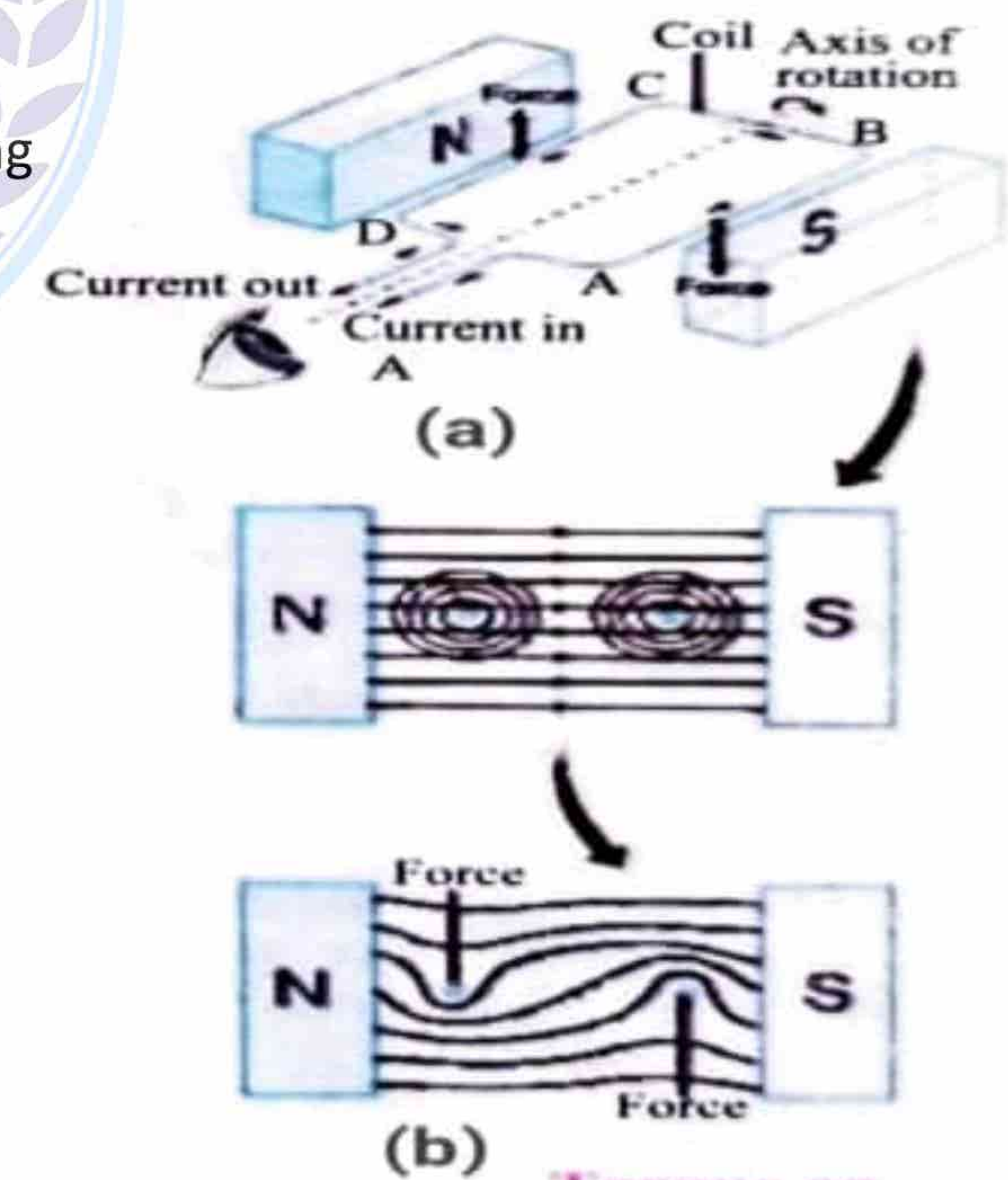
Brushes

The brushes are mounted on the commutator and are used to inject the current from the DC source into the armature.

Working

A current carrying coil in a magnetic field experiences a turning effect. In figure (a) below, 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 these two sides.
b. The side AB next to the South pole experiences a force. The direction of the force can be determined using Fleming's left-hand rule or the right-hand slap rule.
c. The side CD experiences a force that acts in the opposite direction.



Torque on D.C motor

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.

Q9. Define Electromagnetic.

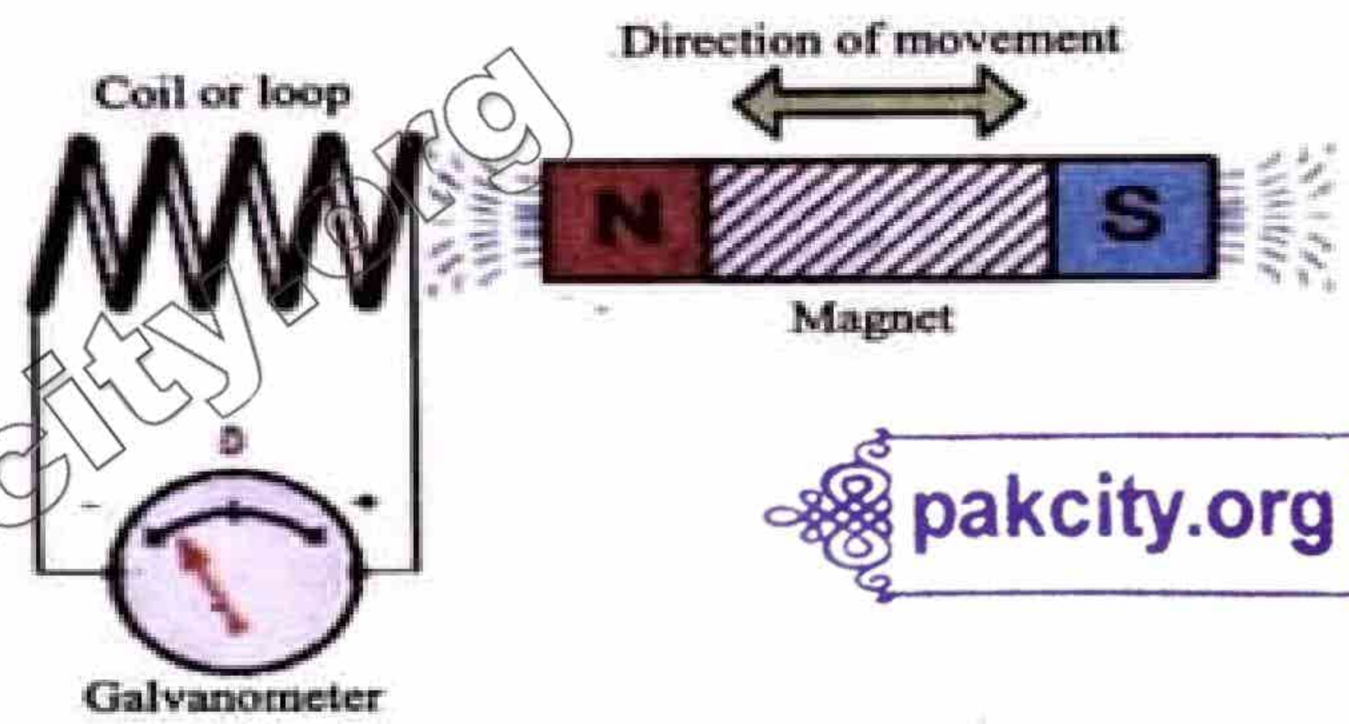
Electromagnetic or magnetic induction

Electromagnetic or magnetic induction is the production of an electromotive force across an electrical conductor in a changing magnetic field.

Q10. How magnetic field can induce e.m.f in a circuit

Changing magnetic field can induce e.m.f in a circuit Electromagnetic Induction by a Moving Magnet

Faraday demonstrates that magnetic fields can create currents as illustrated in figure below. 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.



changing magnetic produced induced e.m.f

When the magnet stops moving and is held stationary with respect to the 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.

Electromagnetic Induction by a Moving Coil

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.

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.

Q11. What do you know about Faraday's Law of Induction?

Faraday's Law of Induction

Statement: 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".

Mathematically: According to Faraday's law

$$\varepsilon \, \alpha \frac{d\emptyset}{dt}$$

$$\varepsilon = N\frac{d\emptyset}{dt}$$

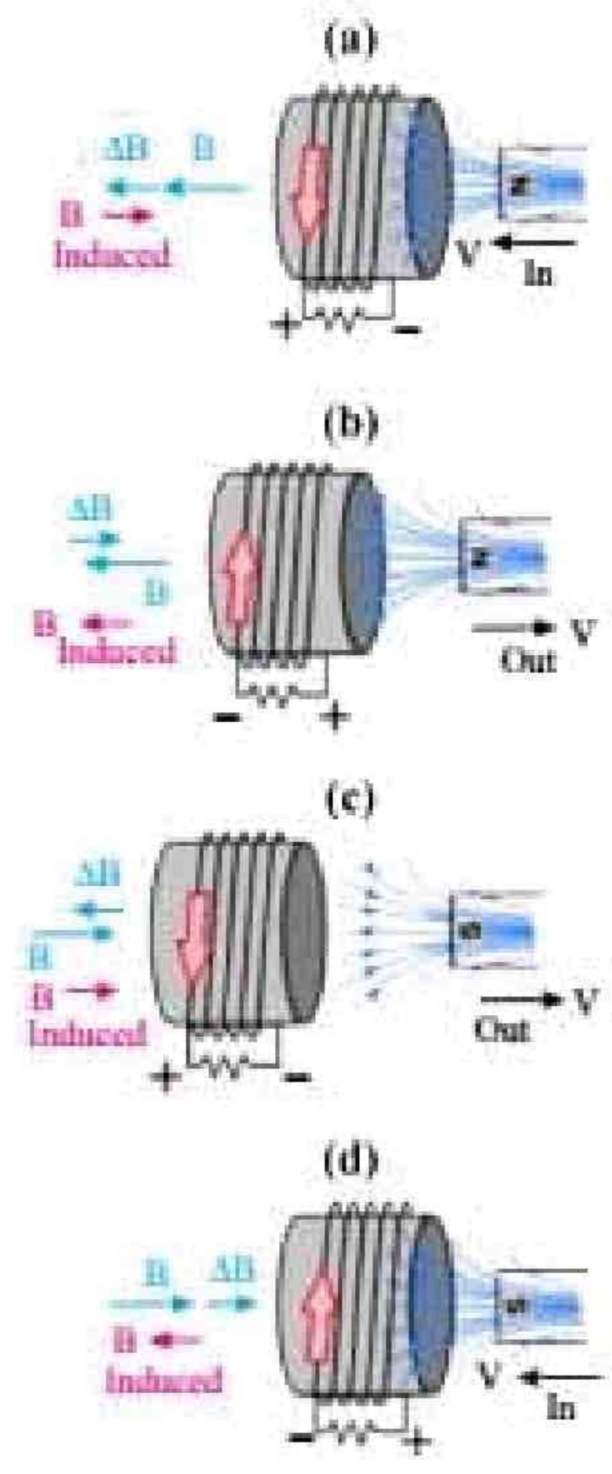
Where:
ε = Induced emf
$d\emptyset$ = change in magnetic flux N = No of turns in coil

Q12. Discus the Factors affecting the magnitude of an induced e.m.f

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 '', 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.



Magnetic field induced by magnetic current

Q13. State and explain Lenz's law

Lenz's law of electromagnetic induction

Statement: 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.

Explanation: Below illustration showing that, if magnetic field "B" is increasing, the induced magnetic field will oppose it in
As illustrated in figure (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.

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.

According to Faraday's law that the magnitude of the EMF induced in the circuit is proportional to the rate of change of flux.

$$\varepsilon \ \alpha \frac{d\emptyset_B}{dt}$$

$$\varepsilon = N\frac{d\emptyset_B}{dt}$$

Where:
ε = Induced emf
$d\emptyset_B$ = change in magnetic flux N = No of turns in coil

Q14. Describe the comparison between Lenz's Law and Conservation of Energy

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.

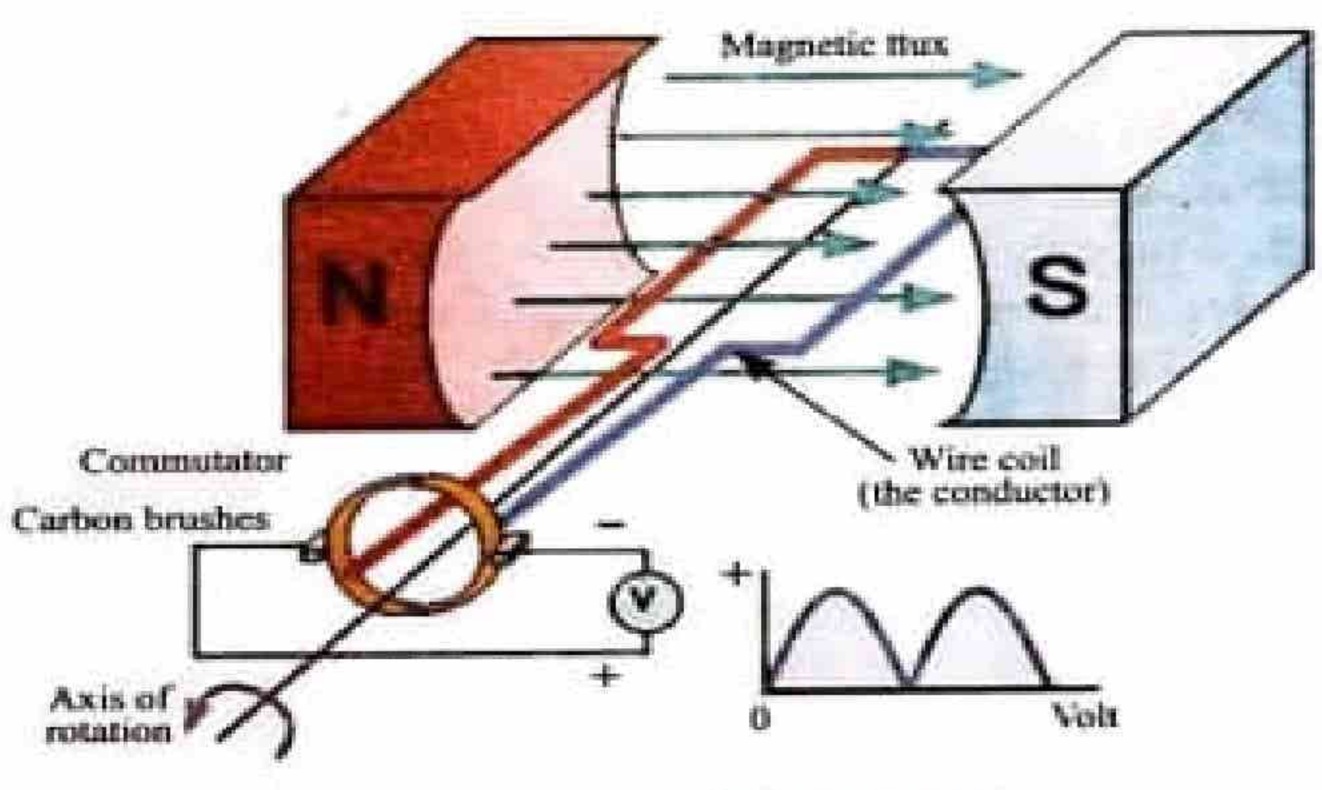
Because of this, it is easy to understand that the conservation of energy would be violated if Lenz's law did not state that the induced current must produce a magnetic field that opposes the field that originated it.

Q15. Describe the comparison between Lenz's law and Newton's third law of motion

Lenz's law and Newton's third law of motion

Lenz's law states that in electromagnetic induction, the direction of induced current is such that it opposes cause of its creation. Remember the experiment of moving magnet towards and away from a coiled wire. The galvanometer needle deflects towards right on moving magnet towards left the coil.

Here, the third law of motion is followed because direction of induced current is opposite to the force which we apply. Hence action i.e. motion of magnet and reaction i.e. induction of current are equal and opposite.



A.C generator

what is A.C generator

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".

Q16. Define Mutual induction. Also derive its formula.

When an electric current passing through a primary coil changes with time, an emf is induced in the secondary coil. This phenomenon is known as mutual induction and the emf is called mutually induced emf.

Derivation

The secondary coil's e.m.f. is proportional to the primary coil's rate of change of current. Thus:

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

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

–ve sign is due to Lenz's law.

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

Hence:

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

Q17. What is Transformer? Describe its construction and working

Transformer

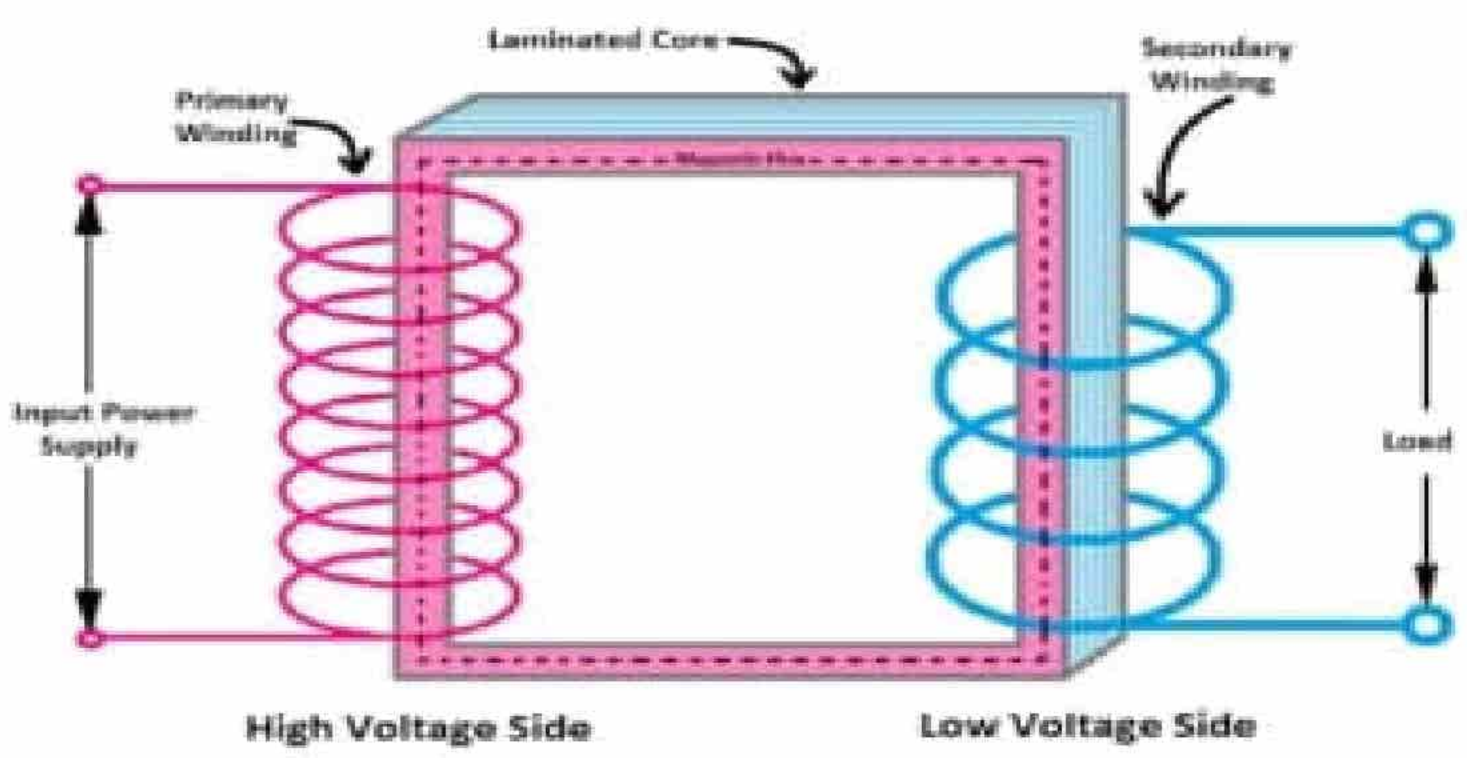
Transformer is a static machine used for transforming power from one circuit to another without changing the frequency. It operates on an AC supply.

Working principle

Transformers operate based on the principle of mutual induction.

Construction

It consists of two coils 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.



Main Parts of Transformer

Working

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.

Factors on which secondary voltage depends:

The secondary voltage (V_s) is proportional to the primary voltage (V_p). The ratio of the number of turns on the secondary coil (N_s) to the number of turns on the primary coil (N_p) also affects the secondary voltage, as illustrated by the following expression.

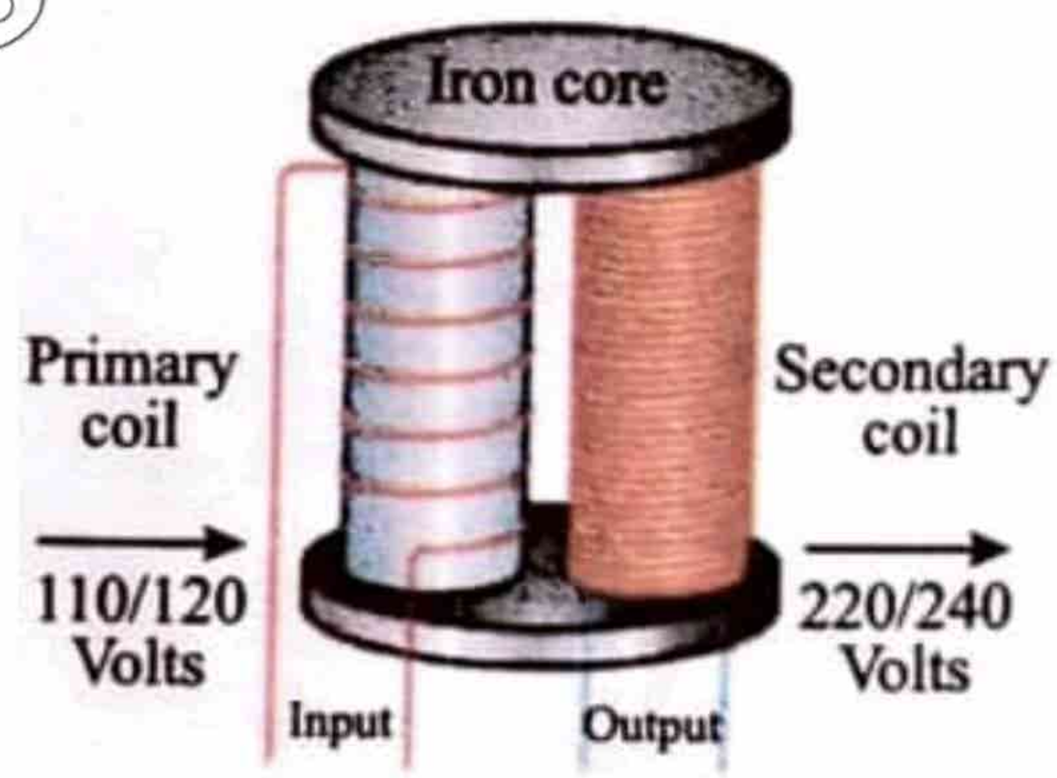
$$\frac{V_s}{V_p} = \frac{N_s}{N_p}$$

Q18. List and discus the Types of transformers

Types of transformers

The types of transformers are following.

1. Step up transformer.
2. Step down transformer



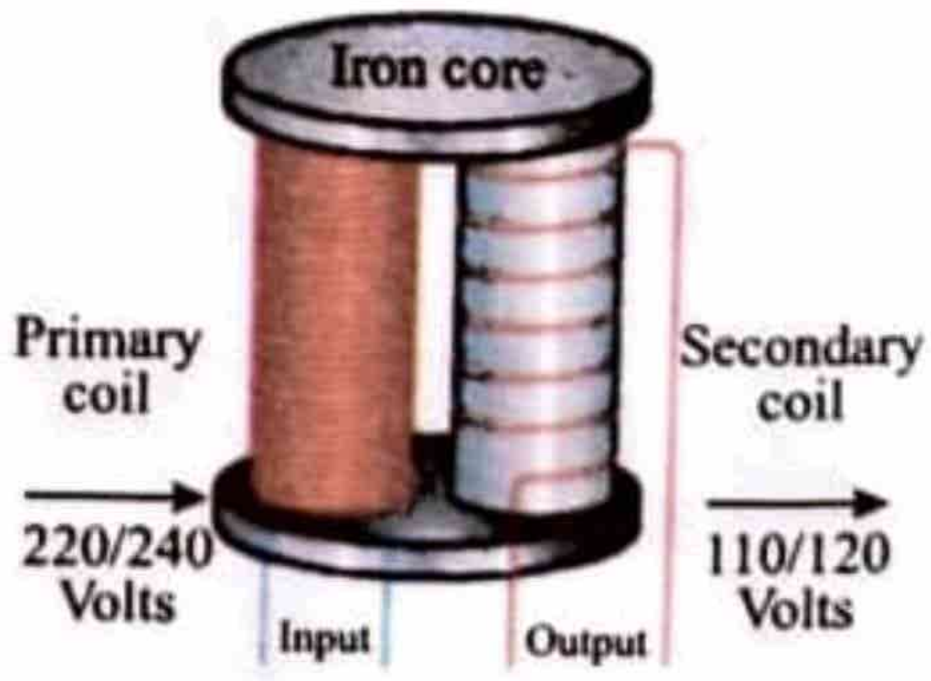
(a)
Step up transformer

1. **Step up transformer:** The transformer is referred to as a step-up transformer if the secondary voltage exceeds the primary voltage.
2. **Step down transformer:** A step-down transformer is one in which the secondary voltage is lower than the primary voltage.

Ideal transformer

Definition

An ideal transformer dissipates no power.



(b)
Step down transformer

Mathematically

We may write the following mathematical expression for such a transformer

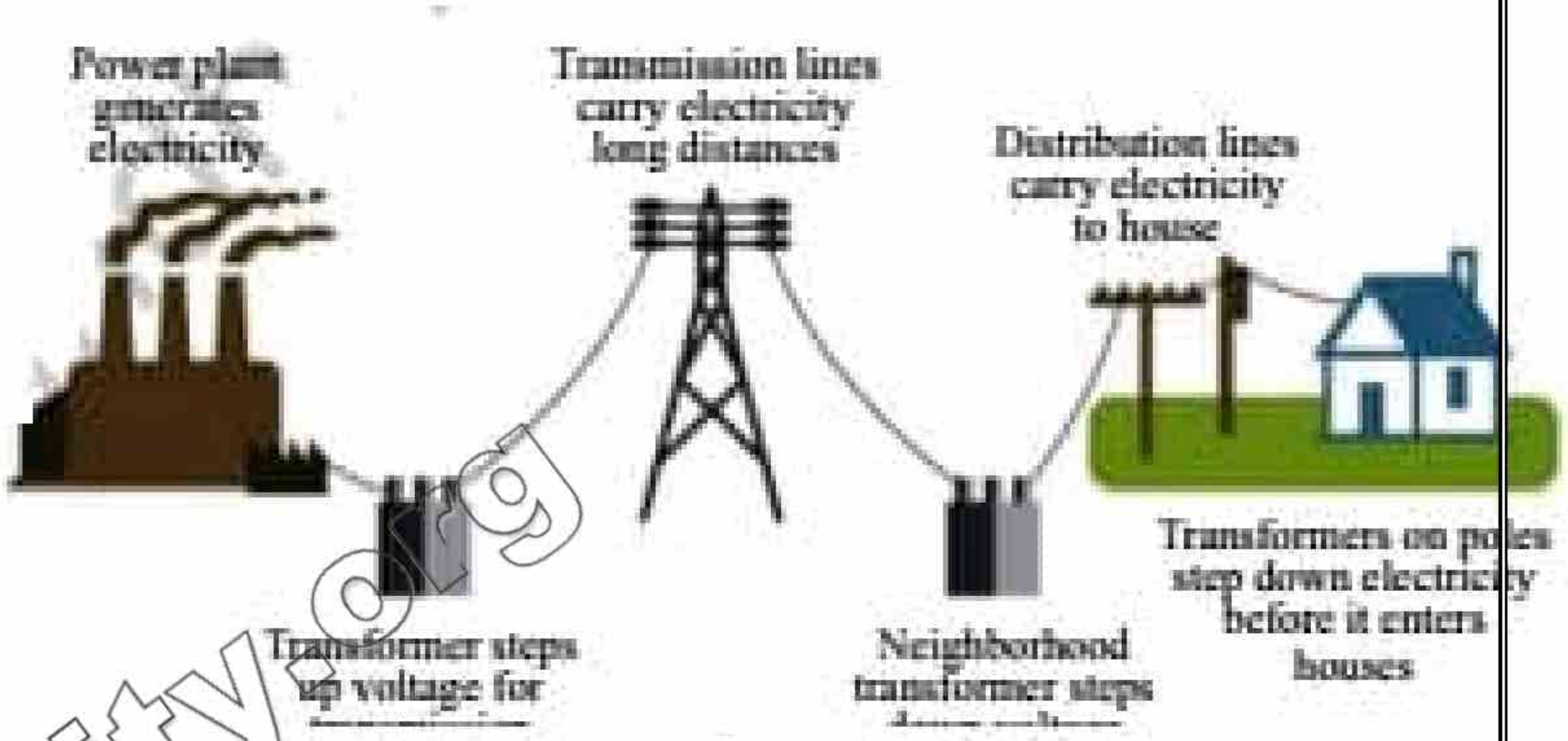
$P_p = P_s$

$$V_p I_p = V_s I_s$$

Q19. Describe the Role of Transformer in Power Transmission

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.



Power transmission from power house to residential area

Q20. **What are the Daily life applications of transformers?**

Daily life applications of transformers

There are several ways a transformer can be used in our daily life.

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.

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 affect each other (d) a single magnetic pole does not exist
2. What is the direction of the magnetic field inside a bar magnet?
(a) from north pole to south pole (b) from south pole to north pole
(c) from side-to-side lines (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. AD.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 ratio of a transformer is 10. It means
(a) Is = 10 Ip (b) Np= 10 Ns (c) Ns =10 Np Vs = 10 Vp Ans:

1.a single magnetic pole does not exist	2.there are no magnetic field lines	3.magnetic compass
4.Increases	5.electrical energy into mechanical energy	6.the commutator
7.energy	8.increases the input voltage	9.$V_s = 10\ V_p$

Numerical

1. A wire carrying 4A current and has length of 15 cm between the poles of a magnet is kept at an angle of 30P 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° with the plane of the loop. What is the magnitude of torque on the loop? (4.8×10^{-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).