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Chapter # 15

ELECTROMAGNETISM

COMPREHENSIVE QUESTIONS:

Give an experiment response to the following questions.

Q1. Describe an experiment to show that the steady current carrying wire produces a magnetic field around it. What is the direction of this magnetic field?

Ans: Magnetic Field:

Definition:

The region around a magnet where the effect of that magnet can be felt is known as magnetic field. The magnetic field can be represented by magnetic field lines.

Magnetic field due to straight steady current carrying wire:

The magnetic field produced by steady current carrying wire can be described with the help of following experiment.

Experiment:

Consider a long straight current carrying wire which is fitted vertically in a piece of card board as shown in figure. Now place some iron filings (fragments) on the whole card board. As we turn on the current in the wire, the iron fillings will arrange themselves in the form of concentric circles around the wire. This experiment shows that the orientation of a magnetic field around a current carrying wire is circular because as the current is turned on in the wire, it produces magnetic field around itself, this magnetic field has caused the iron filings to form concentric circles around the wire.

Detection of Magnetic field in current carrying wire:

We can detect the presence of magnetic field due to deflection of compass needle.

Case 1:

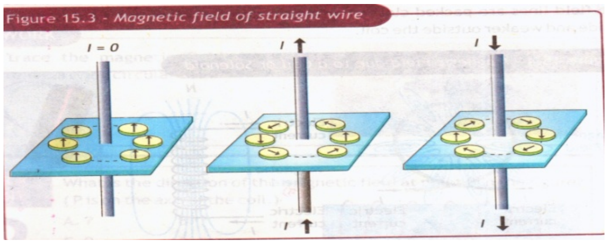
When there is no current in the wire, the compass needle shown no defection as shown in fig (a).

Case 2:

When current flows through the wire in updated direction, the magnetic field exist around the conductor in circular form in anticlockwise direction as shown in figure (b).

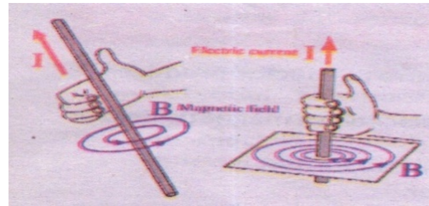
Case 3:

When the direction of current reverses, the magnetic field also reverses and exists around the conductor in clockwise direction as shown in fig (c).



Direction of Magnetic field:

The direction of magnetic field from a current carrying wire can be determined by using right hand Rule-I. This rule states that, "if the current carrying wire is hold by the right hand with the thumb in the direction of current, then the fingers encircle the wire in direction of the field.



Q2. How the magnetic field of wire increases and resembles more like that from a permanent magnet, if the wire is formed in a circular coil? [Hint: consider the magnetic field of a single coil and then a series of coil.]

Ans: <u>Magnetic field due to a coil:</u>

When wire is shaped into the loop or coil and steady current is applied through it, the loop behaves like a magnet. By applying the right hand rule around a loop of wire carrying current, we see that the magnetic field around a loop of wire carrying current is in same direction coming in and going out of coil, forming a north and south pole like bar magnet. So, the field setup by a current loop resembles to the field of a bar magnet.

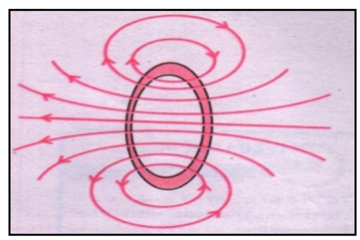
<u>Strength of Magnetic field of a coil:</u>

As the field lines cannot cross, these lines are packed closer together inside. Therefore, the field is stronger inside and weaker outside the coil.

<u>Magnetic field due to a solenoid:</u>

<u>Definition:</u>

If a long straight wire is wrapped into a coil of several closely spaced loops, the resulting device is called solenoid or an electromagnet.



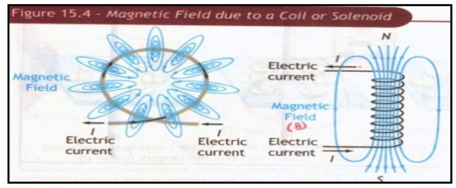
<u>Solenoid as a magnet:</u>

When current is passed through a solenoid, a uniform magnetic field setup by solenoid mostly resembles to the field of a bar magnet. This means that one end of the solenoid acts as the South Pole of a magnet and the other end acts as the North Pole of a magnet.

<u>Strength of magnetic field of solenoid:</u>

The magnetic field is strong along the axis of solenoid and weaker outside. For a tightly wound solenoid, the field in the interior space is very uniform and strong. So, the strength of magnetic field inside a solenoid increases with current and depend upon number of coils per unit length.

Figure 15.4 - Magnetic Field due to a Coil or Solenoid



<u>Direction of Magnetic field for solenoid:</u>

In case of solenoid (spring shaped coil), the direction of magnetic field can be determined by using right hand rule-II

Right hand rule-II for a solenoid:

Curl the fingers in the direction of current around the coil or solenoid and the extended thumb will point in the direction of north of a magnet. This rule is for direction of conventional current flow of positive charges. For electronic current flow, the same rule is applied but with left hand.

Q3. Explain the force on a current carrying wire in a magnetic field.

Ans. Force on a current carrying wire (conductor) in a magnetic field:

Definitions:

When current carrying wire is placed in a magnetic field, charges flowing through the wire interact with the external magnetic field and thus the wire experiences a force (magnetic force). This force is denoted by "F_B".

Explanation:

The magnetic force on a current carrying wire can be shown by following experiment.

Experiment:

Consider a wire is connected to a battery and passing through a U-shaped magnet as shown in figure. It is observed that the wire experiences a force which is perpendicular to both the direction of current "I" and the direction of magnetic field "B". If we reverse the direction of current, the direction of force is also reversed.

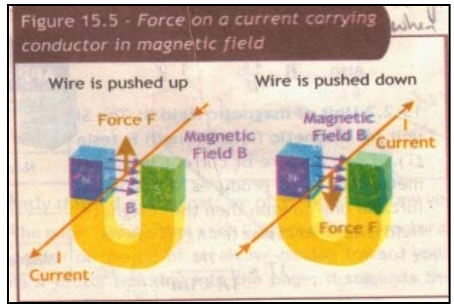


Figure 15.5 - Force on a current carrying conductor in magnetic field

Mathematical derivation:

On the basis of experiment, we can find that magnetic field exerts magnetic force (F_B) on a current carrying wire when placed inside the magnetic field. The magnitude of this force depends upon the following factors.

1. The force is directly proportional to the strength of magnetic field "B". i.e.,

$F_B \propto B$ ------(1)

2. The force is directly proportional to current "I" flowing through the wire i.e.

$F_B \propto I$ ------ (2)

3. The force is directly proportional to the length "L" of wire inside magnetic field i.e.

$F_B \propto L$ ------ (3)

4. The force is directly proportional to the sine of angle between B and I i.e.,

$F_B \propto \sin\theta$ ------ (4)

By combining all 4 equations, we get

$F_B \propto BIL \sin\theta$

Or

$F_B = kBIL \sin\theta$-------- (5)

For SI units, k=1, therefore eq. (5) will become,

$F_B = BIL\sin\theta$ --------- (6)

Equation (6) represents the magnitude of magnetic force acting on a current wire.

Maximum magnetic force (F_B): -

The magnetic force (F_B) will be maximum, when the current "I" carrying wire is placed perpendicular to the external magnetic field "B", so, the angle between I and B is 90^o i.e., $\theta = 90^o$

$F_B = BIL \sin 90^o$ $\therefore \sin 90^o = 1$

$F_B = BIL\,(1)$

$\mathbf{F_B = BIL}$

Or

$\mathbf{B = \frac{F_B}{IL}}$

Minimum magnetic Force: -

The magnetic force (F_B) will be minimum, when the angle between current direction and magnetic field is O^o i.e. they are parallel to each other ($\theta = 0^o$).

$F_B = BIL \sin 0^0$ $\therefore \sin 0^0 = 0$

$F_B = BIL\,(0)$

$F_B = 0$

Unit of Magnetic field (B):

The SI unit for magnetic field strength is tesla (T), where

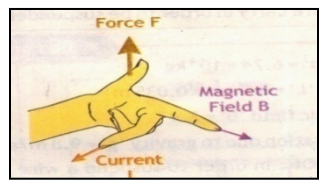
$1T = \frac{1N}{1A \times 1m}$

Direction of Force:

Fleming's left hand rule or right hand rule III is used to determine the direction of force on a current carrying wire in magnetic field.

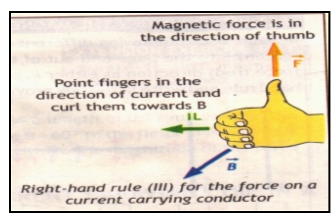
Fleming's left hand Rule:

In Fleming's left hand rule, the thumb and the first two fingers of the left hand are set at right angles to each other. With the first finger pointing in the direction of the field, the second finger pointing in the direction of current, the thumb will give the direction of force.



Right-Hand Rule-III:

In right hand rule-III, open up your right hand. Point your fingers in the direction of magnetic field and your thumb in the direction of current. The palm of your right hand will be in the direction of force on a current carrying wire placed in magnetic field.



Right-hand rule (III) for the force on a current carrying conductor

Q4. Explain the torque on current carrying coil in a magnetic field.

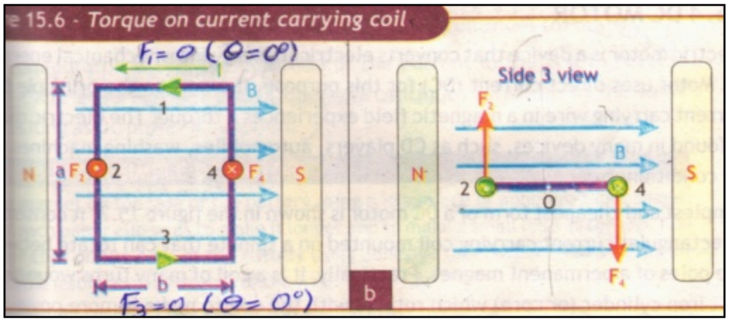
Ans: Torque on a current carrying coil in a Magnetic field:

Definitions:

When a current carrying coil or loop is placed in a uniform magnetic field, it experiences a net force; this force can exert torque on the coil or loop of wire due to which the coil will rotate.

Explanation:

Consider a rectangular coil having four (1,2,3, and 4) sides of length 'a' and 'b' carrying a current "I" in the presence of a uniform magnetic field "B" directed parallel to the plane of the loop as shown in figure.



As current flows in all sides of the loop, so each side will experience a force given by

F_B = BIL sin θ ---------- (i)

The magnitudes of this force on each side will be:

Magnitude of force on side 1 and 3:

1. The magnetic force on sides 1 and 3 will be zero because these sides (wires) are parallel to the magnetic field i.e., $\theta=0^o$, so eq (i) becomes

$F_1=F_3=BIL\sin 0^o$

As length for sides 1 and 3 is equal to "b", therefore

$F_1=F_3=BIb\sin 0^o$

$F_1=F_3=BIb\,(0)$

$F_1=F_3=0$ ------- (ii)

So, torque acting on sides 1 and 3 will be

$\tau=F\times d \qquad \therefore F = 0$

$\tau=0\times d$

$\tau=0Nm$

If no magnetic forces act on side 1 and 3 then torque will be zero.

Magnitude of sides 2 and 4:

The magnetic force on sides 2 and 4 will be maximum because these sides are perpendicular to the magnetic field i.e. $\theta=90^0$. These forces are equal in magnitude but opposite in direction which makes a couple so, eq. (i) becomes,

$F_2=F_4=BIL\sin 90^o$

As length of sides 2 and 4 is equal to "a" therefore

$F_2=F_4=BIa\sin 90^o \qquad \therefore \sin 90^o=1$

$F_2=F_4=BIa\,(1)$

$F_2=F_4=BIa$ ------- (iii)

So, torque acting on sides 2 and 4 will be

$\tau=F\times d \qquad \therefore F = BIa \;\&\; d=b$

$\tau=BIa\times b$

$\tau=BIab \therefore ab$ = Area of coil=A

So,

$\tau=BIA$ -------- (iv)

Where eq. (iv) represents a torque on current carrying oil in a magnetic field. Thus, a couple will always produce torque. If the loop is pivoted so that it can rotate about point "O". So these two forces F_2 and F_4 produces clockwise torque in the loop and loop will rotate along the axis of rotation.

Q5. Explain the working of DC motor.

Ans. <u>DC Motor:</u>

<u>Definition:</u>

DC motor is an electrical device that converts electrical energy into mechanical energy. DC motor uses direct current (DC) for this purpose.

<u>Working Principles:</u>

It works on the principle that a current carrying wire in a magnetic field experiences a torque which tends to rotate the coil.

<u>Construction:</u>

DC motor consists of the following parts as shown in figure.

1. <u>Armature (coil):</u>

It consists of a rectangular current carrying coil which is would on soft iron cylinder (or core) that rotates the coil.

2. <u>Strong field magnet:</u>

Armature coil is placed between 2 poles of a permanent magnet which provide strong magnetic field.

3. <u>Split ring type Commutator:</u>

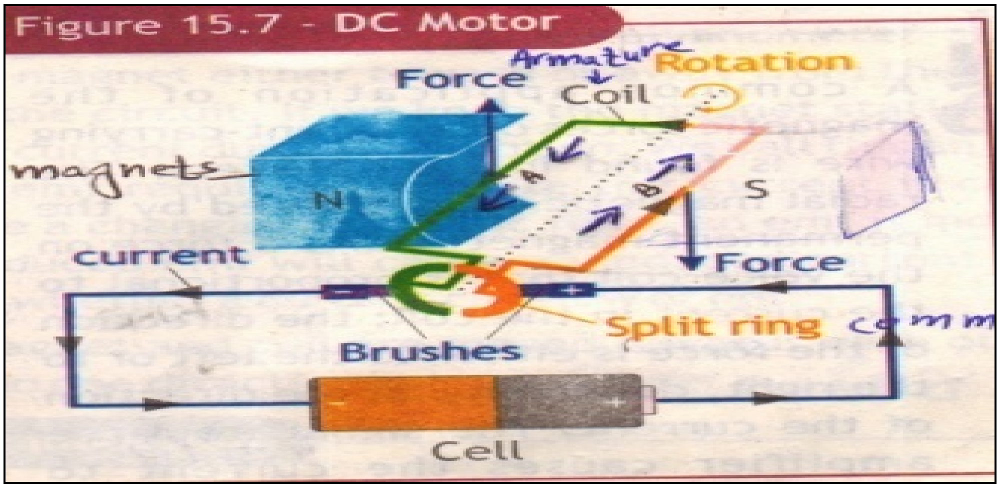
Is consists of 2 halves of a metallic split ring. The two ends of armature coil are connected to these 2 halves of ring called a commutator. A commutator reverses the direction of current in armature coil.

4. <u>Brushes:</u>

Two carbon brushes are connected to the battery which allows the ring to rotate. There brushes act as contact between commutator and terminal battery.

5. <u>Battery:</u>

A battery is connected across the carbon brushes. It supplies current to armature coil.



Working of DC Motor:

Consider, when the current is switched on, the 'a' coil is in horizontal position where side "A" is in left hand side and side "B" is in right hand side of coil as shown in the figure. As current flows through coil, side (arm) A and B experience a magnetic force. According to Fleming's left hand rule, side "A" of coil experiences force in upward direction and side "B" experiences force in downward direction. Both these forces are equal and opposite, which makes a couple. The couple produces torque that acts upon the coil and causes it to rotate in the clockwise direction until the coil reaches the vertical position. At this position, the contact of commutator and brushes break. Due to this, supply of current to coil is cut off. Hence, no force acts on sides (arms) of coil. But coil goes on rotating due to the inertia of motion of coil until commutator again comes in contact with brushes.

When commutator come in contact with brushes after rotation, direction of current flow in the coil is reversed. Now the side "A" is on right hand side with a downward acting on it and side "B" is left hand side with upward force acting on it. Thus, the coil of DC motor continues to rotate in the same clockwise direction as long as the battery is supplying the current to the coil. In this way, DC motor converts electrical energy to mechanical energy which is utilized for different types of work.

Uses of DC motor:

The electric motor is used in many devices such as CD players, automobiles, washing machines, air conditioners and refrigerators etc.

Q6. Describe the phenomena of electromagnetic induction. List the factors effecting electromagnetic induction?

Electromagnetic induction: -

Definition:

"When magnetic field through loop of wire is changed, current is found to flows in the loop, the phenomena is called electromagnetic induction"

Or

"The phenomena in which an induced emf is produced in a coil due to change in magnetic flux is called electromagnetic induction"

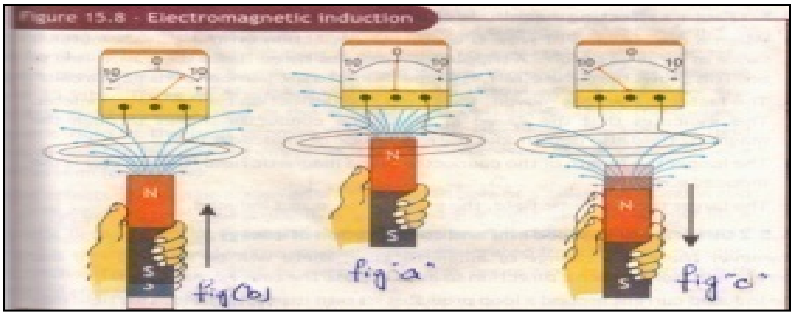
Explanation: -

A changing magnetic field induces an emf. The current in a circuit due to a changing magnetic field is called an "induced current". An induced current is not caused by a battery; it is a completely new way to generate a current by changing a magnetic field. So, there is an induced current in a coil of wire only if the magnetic field passing through the coil is changing.

Experiment: -

The phenomena of electromagnetic induction can be demonstrated by a simple experiment. Consider a coil of wire connected to a galvanometer as shown in figure. When the magnet is stationary (even inside coil), galvanometer shows no current. But when we move the magnet either towards or away from the coil, the galvanometer shows current in the circuit. If we keep the magnet stationary and move the coil, we again detect a current during the motion. We call this an induced current and an emf required to create this current is called an induced emf. Whenever, we have a changing magnetic field, an emf is induced, if the circuit is completed, the induced emf will cause an induced current to flow.

It should be noted that when magnet and coil are moved towards each other, the galvanometer shows deflection in one direction. Whereas, when the magnet and the coil are moved away from each other, the galvanometer shows deflection in the other direction. When both are fixed, no such deflection occurs.



<u>Factors affecting induced emf:</u>

The magnitude of induced emf depends upon the following factors.

1) **<u>Number of turns in the coil: -</u>**
   The induced emf is directly proportional to the number of turns in a coil. Greater the number of loops, larger will be induced emf.
2) **<u>Length of conductor (wire): -</u>**
   The longer the length of the conductor in the magnetic field, the greater is the induced emf.
3) **<u>Strength of magnet: -</u>**
   The larger the magnetic field, (B) the greater will be the induced emf.
4) **<u>Speed of motion of magnet or coil: -</u>**
   The greater the speed at which the magnet is moving, towards and away from the coil, larger will be the induced emf. In other words, the faster the wire is moved, the larger the deflection on the galvanometer.

Q 7: Explain the direction of induced emf and show its relation to conservation of energy.

Ans: <u>Direction of induced emf:</u>

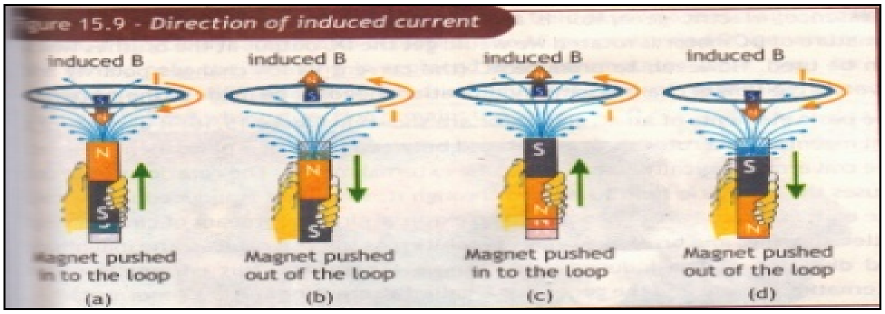
The direction of induced emf is such that it opposes the cause the produces it.

<u>Explanation:</u>

The induced emf causes an induced current in the loop. This induced current produces its own magnetic field called induced field. This field may be weak compared with the external magnetic field. It cannot prevent the magnetic flux through the loop from changing but its direction is always such that it tries to prevent the flux from changing.

Consider a loop and a bar magnet is moved towards and away from it. When we move the north pole close towards the loop, it causes an increase in magnetic field in the loop (in the upwards direction) to oppose the change, the loop itself needs to generate the downward pointing magnetic field i.e. the loop will repel the magnet. The induced magnetic field at the centre of the loop will download, only if the current is clockwise as shown in figure now, if the north pole of bar magnet is pulled away from the loop, there is an upward magnetic field through the loop, but the magnetic field is decreasing as the magnet is moving away. Thus the induced magnetic field of the loop opposes this decrease and point in the upward direction. So the induced current is counter clock wise.

Similar effects can also be observed with the south pole of a magnet pushed in and out of the loop as shown in figure. Thus, it is clear that motion of magnet is always opposed by the magnetic field generated from induced current. It is also known as "Lenz's law"



Conservation of energy and induced emf:

The induced current is produced only when work is done on the magnet by bringing it closer or away from the coil/loop. This mechanical work is converted into electrical energy. Thus, energy is conserved in this phenomenon. If the induced magnetic field is in such a direction as to support its cause, then the moving magnet would have been accelerated towards and away from the loop. This would produce electrical energy without providing any external energy (mechanic energy), which is a clear violation of law conservation of energy.

Q8. Sketch and describe the construction and working of AC generator.

Ans.AC Generator: -

Definition:

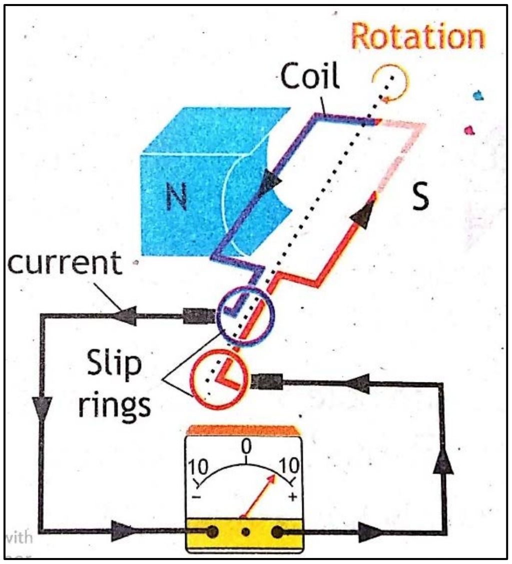
AC generator is an electrical device that converts mechanical energy into electrical energy. AC generator produces "Alternating Current".

Working Principle:

AC generators works on the principle of electromagnetic induction that can be used to generate electricity for practical purposes. For example, an electric generator uses this principle.

Construction:

AC generator consists of the following parts as shown in figure.



1) **Armature:**

It consists of a rectangular coil of large number of turns of copper wire wound over an iron core. The coil is rotated about its axis.

2) **Field Magnet:**
Armature is placed between two poles of a permanent magnet that provide strong magnetic field in which the coil is rotated. The axis of coil is perpendicular to the magnetic field.

3) **Slip rings:**
The ends of the coil are connected with two circular rings called slip rings, these rings rotate with the rotation of coil.

4) **Brushes:**
The connection of external circuit is usually made with the help of two carbon brushes which are fixed and kept in contact with slip rings. The purpose of brushes is to pass current from the armature to the external load resistance.

Working of AC generator:

When current reaches the armature, the coil beings to rotate about its axis. The rotation of the coil causes the magnetic field to change through it, so an emf is induced in the coil. As the coil rotates, the magnitude and direction of the induced emf change after every half of the time period. Therefore, this current is called alternating current and the generator is called alternating current generator or dynamo.

When the coil becomes perpendicular to the magnetic field then the magnetic flux becomes maximum. When the coil becomes parallel to the magnetic field, the magnetic flux becomes zero. Thus, magnetic flux changes continuously and produces electricity.

USES of A.C Generator:

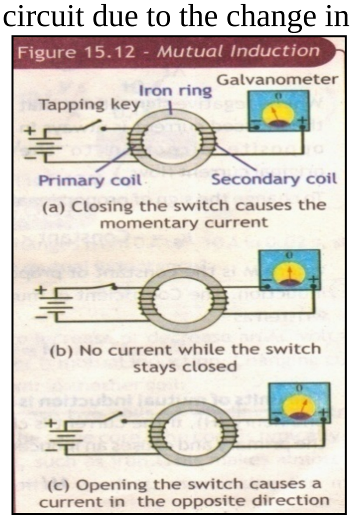
1. It is used to run machines and to provide light in houses.
2. AC generators are also used in power stations (such as Malakand, Tarbela etc.), where it converts K.E into electrical energy.
3. They are also used to convert the chemical energy of petrol and diesel into electrical energy.

Q9. Describe the phenomena of mutual induction.

Ans. Mutual Induction:

Definition:

"The phenomena in which emf is induced in a one (secondary) coil or circuit due to the change in current in another (primary) coil or circuit is called mutual induction.



Explanation:

The phenomena of mutual induction can be explained with the help of an experiment. Consider, two fixed coils placed side by side as shown in figure. The coil that is connected to a battery is called primary coil while the coil that has no source of emf is called secondary coil. Both coils are wound on an iron ring core that is used only to increase the magnetic field produced.

The primary coil is connected to a battery through a tapping key while the secondary coil is connected to galvanometer. It is observed that the galvanometer shows a momentary deflection when the key is pressed. The pointer in the galvanometer returns to zero immediately. If the key is held press continuously, there is no deflection in the galvanometer. When the key is released, a deflection is observed again but in the opposite direction.

From this experiment, when the key was pressed the magnetic field developed by primary coil was changed due to change in current per unit time which induced an emf in secondary coil.

Mathematical Form:

Mathematically, the induced emf (ε_s) in the secondary coil is directly proportional to the rate of current in the primary coil.

$\varepsilon_s \alpha - \frac{\Delta Ip}{\Delta t}$ -------- (1)

Where negative sign shows that the induced current is always in opposite direction to the original current flow.

To change sign of proportionality into equality, equation (1) becomes

$\varepsilon_s = -\text{constant} \times \frac{\Delta Ip}{\Delta t}$

or

$\varepsilon_s = - M \times \frac{\Delta Ip}{\Delta t}$ ------- (2)

Where "M" is the constant of proportionality and is called as coefficient of Mutual induction.

Coefficient of Mutual induction:

The coefficient of Mutual induction can be written as:

$M = -\frac{\varepsilon s}{\Delta Ip/\Delta t}$

OR

$M = \frac{\varepsilon_s \times \Delta t}{\Delta Ip}$

Unit of Mutual induction:

The SI unit of mutual induction is "Henry" which is denoted by "H". The mutual inductance of two coils will be 1 henry(H), if the current is changing at the rate of 1 ampere per second in the primary coil and causes an induced emf of 1 volt in the secondary coil i.e.,

1H = 1V ×1S /1A

Or

1H = Vs/A

Q10.What are transformers? On what principle it works? Also describe the purpose of transformers in
AC circuits.

Ans. **Transformers:**

Definition:

A transformer is a device which is used to increase or decrease an AC voltage or current level.

Or

A device which steps up or steps down AC voltage is called transformer.

Working Principle:

A transformer works on the principle of mutual induction i.e. changing current in primary coil produces an Induced emf in the secondary coil.

Construction:

The key components of a transformer are two coils or windings, electrically insulated from each other but wound
on same core which is made of iron (as shown in fig). The windings (coil) to which power is supplied is called
the primary coil while the winding (coil) from which power is drawn is called the secondary coil.

Working:

When an alternating voltage (V_p) is applied to the primary coil then it produces an alternating current in it. This current produces a continuous change in magnetic flux which produces an induced emf in the secondary coil.

This magnetic flux depends upon the number of turns (N_p) in primary coil. The induced emf depends upon the number of turns (Ns) in the secondary coil. The ratio N_s/N_p is referred to as a **turn's ratio** of the transformer.

Mathematical Form:

Mathematically, it can be written as:

$$\frac{Vs}{Vp} = \frac{Ns}{Np}$$

Where, V_s represents the voltage across the primary coil
V_p represents the voltage across the secondary coil
N_s represents the number of turns in primary coil
N_p represents the number of turns in secondary coil.

Step-up transformer:

If N_s is greater than N_p ($N_s > N_p$) and the secondary (output) voltage is greater than the primary (input) voltage ($V_s > V_p$). In such case, the transformer is called step-up transformer.

Step-down transformer:

If N_s is less than N_p ($N_s < N_p$) and the secondary voltage is less than the primary voltage ($V_s < V_p$), such transformer is called step-down transformer.

Purpose of transformers:

1. The main purpose of transformers is to transfer electricity from power plants to household users without any major losses.
2. It is used for increasing or decreasing alternating voltage. The power companies use transformers to
   step-up the voltage to high level. It reduces the power losses an A.C circuits. If power plant produces a voltage of 13000 volts, then such voltage can be raised to 500,000 volts with the help of step-up
   transformers. Similarly, for domestic use this high voltage can be reduced to 240 volts by using step-down transformers that are installed outside our homes.
3. It is used in design of circuits for communication in different devices i.e. radio, T.V etc.

CONCEPTUAL QUESTIONS

Give a brief response to the following questions.

Q1. Differentiate between electric and magnetic fields.

Electric field	Magnetic Field
Definition	
The region around a charge where its effects can be felt is called electric field.	The region around a magnet where its effect can be felt is called magnetic field.
Cause	
Electric filed can be caused by both stationary as well as moving charges.	Magnetic field can only be caused by moving charges
Field Lines	
The lines formed by electric field are not continuous.	The line formed by magnetic field is continuous and form closed loops.
Magnitude and direction	
Electric field can change both the magnitude and direction of a charged particle.	Magnetic field can change the direction of a charged particle only.
Unit	
The SI unit of electric field strength is Newton per Coulomb (NC^{-1}).	The SI unit of magnetic field strength is tesla (T).

Q2. Can an electron at rest be set into motion with a magnetic field?

Ans. No, an electron at rest cannot be set into motion with a magnetic field. As we know that,
The magnitude of magnetic force on charged particle is given by

$F_B = BIL\sin\theta$-------(i)

For the electron at rest, I=0, so eq. (i) becomes

$F_B = B(0)L\sin\theta$

$F_B = 0$

It shows that charged particle at rest experiences no force in a magnetic field. As no work is done by the magnetic field, then there will be no change in the velocity of charged particle due to magnetic field. Thus an electron at rest cannot be set into motion with a magnetic field.

Q3. Which is more likely to show deflection in compass needle, AC current or DC current? Explain.

Ans. Direct Current (DC) is more likely to show deflection in compass then Alternating Current (AC). As we know that when there is a current in the wire, magnetic field produces around it. When the direction of current is reversed, the direction of magnetic field will also be reversed.

In case of DC current, magnetic field will have only one single direction and also does not change due to which the compass needle will be deflected in the direction of magnetic field. While in case of AC, current changes its direction continuously, and hence the magnetic field produces by AC also changes due to which the compass needle will show almost no deflection.

Q4. A constant magnetic field is applied to a current carrying conductor. What angle should the wire
make with the field for the force due to be (a) maximum (b) minimum?

Ans. We know that a magnetic force on a current carrying conductor is given by

F_B= BIL sin θ ----- (i)

(a) <u>For maximum Force:</u>

The magnetic force will be maximum, when the angle between magnetic field "B" and current (I) direction is 90°. i.e θ = 90°. So, eq (i) becomes

F_B= BIL $\sin 90° \therefore \sin 90° = 1$

F_B=BIL (I)

$F_{B\,(max)}$ =BIL

(b) <u>For minimum Force:</u>

The magnetic force will be minimum, when the angle between magnetic field (B) and current (I) is 0°. i.e. $\theta = 0°$. So equation (i) becomes

F_B= BIL $\sin 0° \therefore \sin 0° = 0$

F_B=BIL (0)

$F_{B\,(min)}$=0

Q5. Why does a compass needle points North?

Ans. We know that like magnetic poles repel while dislike poles attract each other. A compass needle is nothing but a tiny suspended magnet inside it. On the other hand, earth also behaves like powerful bar magnet having two poles i.e. magnetic north pole and magnetic South Pole, nearly coinciding with geographic south and geographic north respectively.

So the earth's magnetic field interacts with other magnets lying in it. Thus, the north end of a compass magnet is drawn by the magnetic south pole of earth for alignment because the earth's magnet north pole attracts the "north" ends of other magnets which is technically the "south pole" of earth's magnetic field. That is why a compass needle points north.

Q6. How can a magnetic field be used to generate electric current?

Ans. In case of electromagnetic induction, a magnetic field is used to generate electric current where a changing magnetic field produces an induced emf causing electric current in closed loop of wire. For example, in generators; principle of electromagnetic induction is applied. Under which a closed loop of wire is rotated inside a magnetic field which causes a changing field inside the loop that produces induced current in the loop.

Q7. What would happen if we use a slip ring to drive a DC motor?

Ans. A slip ring is a continuous ring which provides a continuous transfer of power. Specifically slip rings are used in AC motors and AC generators. They are not suitable to be used in DC motors. So, to keep the torque in one direction, split rings or commutators are used. If split rings are used in DC motors instead of split rings, then continuous rotation of the coil of the DC motor will not be possible. The coil will oscillate, not rotate along a single direction because after every half a cycle, the direction of current will reverse. Then armature coil of DC motor will start motion in reverse direction. So, there will be no complete rotation (i.e. no work will be done). Therefore, slip rings are not suitable to be used in DC motors.

Q8. The primary coil of a transformer is connected to a DC battery. Is there an emf induced in the
secondary coil? Why?

Ans. If the primary coil of a transformer is connected to a DC battery, no emf will be induced in the secondary coil because there will be no mutual induction due to constant current. As we know that the transformer works on the principle of electromagnetic induction. Under this principle, a changing current (AC) in primary coil will produced an induced emf in the secondary coil. Hence, no emf is induced in the secondary coil when DC battery is connected to the primary coil because it provides uniform current.

NUMERICAL QUESTIONS

Q1. A 1.5m long wire carries a current of 5A, at right angle to a uniform magnetic field of 0.04T. Determine the force exerted on the wire?

Data:

Length of wire =L=1.5m
Current in wire =I = 5A
Magnetic field =B = 0.04T
For right Angle = θ =90^o

Find:

Magnetic Force = F_B=?

Solution:

We know that
$F_B = BIL \sin\theta$

By putting values,

$F_B=0.04\times5\times1.5\times \sin90^o$ $\therefore \sin90^o =1$
$F_B=0.04\times5\times1.5\times1$
$\mathbf{F_B=0.3N}$

Q2. A wire carrying a direct current of 10.0A is suspended 5.0m east between a house and garage perpendicular to the earth's magnetic field of 5.0×10^{-5}T. What is the magnitude of the force that acts on the conductor?

Ans. <u>Data:</u>

Current in the wire=I=10.0A

Length of wire= L=5m

Magnetic field=B=5×10^{-5}T

For right angle or perpendicular=θ=90^o

<u>Find:</u>

Magnetic Force=F_B=?

<u>Solution:</u>

We know that

F_B=BIL sinθ

By putting values

$F_B=5\times10^{-5}\times10\times5\times\sin90^o$ $\quad\therefore\sin90^o=1$

$F_B=5\times10^{-5}\times10\times5\times1$

$F_B=250\times10^{-5}$

$F_B=2.50\times10^{-5+2}$

$F_B=2.50\times10^{-3}$ N

Q3. A 10cm wire at 30^0 to uniform magnetic field of 0.06T is exerted by a force of 0.024N. What is the current flowing through the wire?

Ans. <u>Data:</u>

Length of wire=L=10cm

$= \frac{10}{100}$

L=0.1m

Angle=θ=30^o

Force acting wire =F_B=0.024N

<u>Find:</u>

Current in the wire=I=?

<u>Solution:</u>

We know that

F_B=BIL sinθ

Or

$$I = \frac{F_B}{BL\sin\theta}$$

By putting values

$$I = \frac{0.024}{0.06\times0.1\times\sin30^0} \qquad \therefore \sin30^0 = 0.5$$

$$I = \frac{0.024}{0.06\times0.1\times0.5}$$

$$I = \frac{0.024}{0.003}$$

I= 8A

Q4. If the current through the primary coil changes from -5A to +5A in 0.05s, such that the induced emf is 2.8V. What is the mutual inductance?

Ans: Data:

Initial current $=I_i=-5A$

Final current$=I_f=+5A$

Time $=\Delta t=0.05sec$

Induced emf$=\varepsilon_s=2.8V$

Find:

Mutual inductance=M=?

Solution:

We know that

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

Or

$$M = \frac{-\varepsilon_{\varepsilon s}\Delta t}{\Delta I_p} \qquad \therefore \Delta_p = \text{If} - \text{Ii}$$

$$M = \frac{-\varepsilon_{\varepsilon s}\Delta t}{I_f - I_i}$$

By putting values

$$M = \frac{-2.8\text{x}0.05}{(+5-(-5))}$$

$$M = \frac{-0.14}{10}$$

M=-0.014 H

$M=-14\times10^{-9}H$ $\therefore 1m=10^{-3}$

M= -14mH

Q5. A transformer connected to a 120-V AC line is to supply 9600V for a neon sign. (a) What is the ratio of secondary to primary turns of the transformer? (b) If the transformer consisted of 257 primary windings, how many secondary windings would there be?

Ans. Data:

Primary voltage$=V_p=120V$

Secondary voltage$=V_s=9600V$

Find:

a. Turns ratio $=\frac{N_s}{N_p}=?$

b. Number of turns in primary coil=N_p=?

Solution:

(a) For finding turns ratio, we know that

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

By putting values

$$\frac{N_s}{N_p} = \frac{9600}{120}$$

$$\frac{N_s}{N_p} = 80$$

(b) Now, for finding "N_s", we know that

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

Or

$$\text{Ns} = \frac{V_s}{V_p} \times \text{Np}$$

By putting values

$$\text{Ns} = \frac{9600}{120} \times 275$$

N_s = 22,000

Q6. How many turns would you want in the secondary coil of a transformer having 400 turns in the primary if it were to reduce the voltage from 220V AC to 3.0V AC?

Ans. <u>Data:</u>

Number of turns in primary coil=N_p=400

Primary voltage=V_p=220V

Secondary voltage=V_s=3V

Find:

Number of turns in secondary coil=N_s=?

Solution:

We know that

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

Or

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

By putting values

$$N_s = \frac{3}{220} \times 400$$

N_s= 5.45

Q7. A transformer steps down a main supply of 220V AC to operate a 12V AC lamp. Calculate the turns ratio of the windings.

Ans. <u>Date:</u>

Primary voltage=V_P=220V

Secondary voltage=V_s= 12V

<u>Find:</u>

Turns ratio = $\frac{N_s}{N_p}$= ?

<u>Solution:</u>

We know that,

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

By putting values

$$\frac{N_s}{N_p} = \frac{12}{220}$$

$$\boldsymbol{\frac{N_s}{N_p} = 0.05}$$

<u>ASSIGNMENTS</u>

<u>Assignment 15.1:</u>

A wire carrying a steady (DC) 30A current has a length of 0.12m between the pole faces of a magnet. The wire is at angle θ=60^o to the field. The magnetic field is approximately uniform at 0.90 T. Determine the magnitude of the force on the wire.

Ans. <u>Data:</u>

Current in the wire =I=30A

Length of wire=L=0.12m

Angle = θ= 60^o

Magnetic field=B=0.90T

<u>Find:</u>

Magnetic force = F_B= ?

<u>Solution:</u>

We know that,

F_B = BILL sinθ

By putting values

F_B=0.90×30×0.12× sin60^o ∴sin60^o =0.866

F_B=0.90×30×0.12×0.866

F_B= 2.8N

<u>Assignment 15.2:</u>

Q2. If the current through the primary coil changes from 0A to -10A in 0.02s, such that the induced emf is 4.3V. What is the mutual inductance?

Ans. <u>Data:</u>

Initial current = I_i = OA

Final current = I_f = -10A

Time = $\Delta t = 0.02_s$

Induced emf = $\varepsilon_s = 4.3V$

Find:

Mutual inductance = M = ?

Solution:

We know that,

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

Or

$M = \frac{-\varepsilon\varepsilon_s\Delta t}{\Delta I_p}$ $\qquad \therefore \Delta I_p = I_f - I_i$

$M = \frac{-\varepsilon\varepsilon_s\Delta t}{I_f - I_i}$

By putting values

$M = \frac{-4.3 \times 0.02}{(-10-0)}$

$M = \frac{-0.086}{-10}$

M = 0.0086 H

$M = 8.6 \times 10^{-3}$ H $\qquad \therefore 1m = 10^{-3}$

Or

M = 8.6m H

Q3. A set-up transformer has a primary coil consisting of 200 turns and a secondary coil consisting of 3000 turn. The primary coil is supplied with an effective AC voltage of 90.0v. What is the voltage in the secondary circuit?

Data:

Number of turns in primary coil = $N_p = 200$

Number of turns in secondary coil = $N_s = 3000$

Primary voltage = $V_p = 90V$

Find:

Secondary voltage = $V_s = ?$

Solution:

We know that,

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

Or

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

By putting values

$V_s = \frac{3000}{200}$

$V_s = 15 \times 90$

$V_s = 1350V$