Introduction

This is a learning as well as an exam preparation video.

At the end of the video are practice assignments for you to attempt.

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Chapter 4: Magnetic Effects of ElectricCurrent

Chapter 4: Magnetic Effects of Electric Current

Magnet

A magnet is a material that produces a field that attracts or repels other such materials of magnetic nature.

Lodestone (Fe3O4) is a naturally occurring magnet. It attracts materials like Iron, Nickel, Cobalt, etc.

A magnet is always bipolar with poles named north and south poles. These two poles always exist together and can not be separated. North pole of a magnet is the side which points to Earth's geographic north when it is freely suspended.

Chapter 4: Magnetic Effects of Electric Current

Magnet

Bar magnet: A bar magnet is a rectangular object, composed of iron, steel or any form of a ferromagnetic substance, that shows permanent magnetic properties. It has two different poles, a north and a south pole such that when suspended freely, the north pole aligns itself towards the geographic north pole of the Earth.

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Magnetic Field and Field Lines

- The space around a magnet in which the force of attraction and repulsion caused by the magnet can be detected is called the magnetic field.
- The curved paths along which iron filings arrange themselves due to the force acting on them in the magnetic field of a bar magnet are called magnetic field lines.

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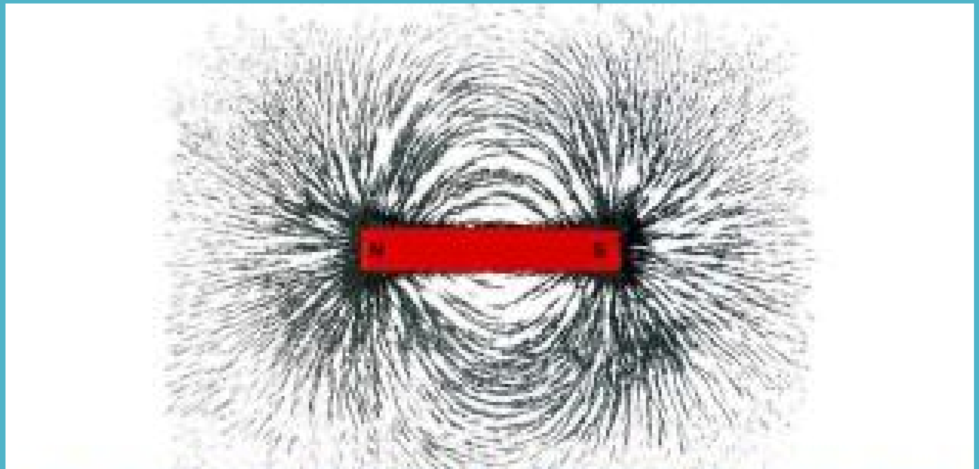
Magnetic Field and Field Lines



Iron filings near the bar magnet align themselves along the field lines

- The direction of the magnetic field at any point is obtained by drawing a tangent to the field line at that point.

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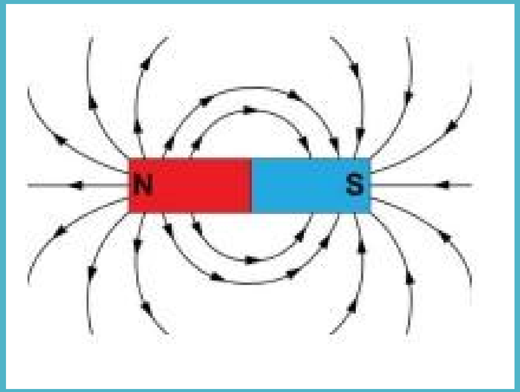
Properties of Magnetic Field Lines

- A magnetic field line is directed from the North Pole to the South Pole outside the magnet.
- A magnetic field line is a closed and continuous curve.
- The magnetic field lines are closer where the magnetic field is strong and farther apart where the magnetic field is weak.
- The magnetic field lines never intersect each other.
- Parallel and equidistant field lines represent a uniform magnetic field.



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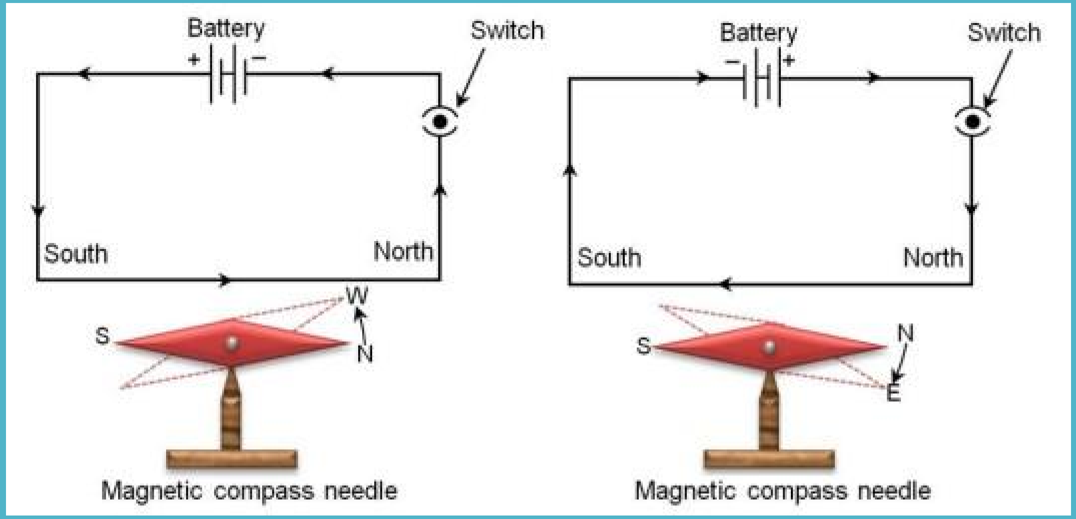
Magnetic Field Due to a Current Carrying Conductor

Oersted's experiment: When electric current flows through a current carrying conductor, it produces a magnetic field around it. This can be seen with the help of a magnetic needle which shows deflection. The more the current, the higher the deflection. If the direction of current is reversed, the direction of deflection is also reversed.



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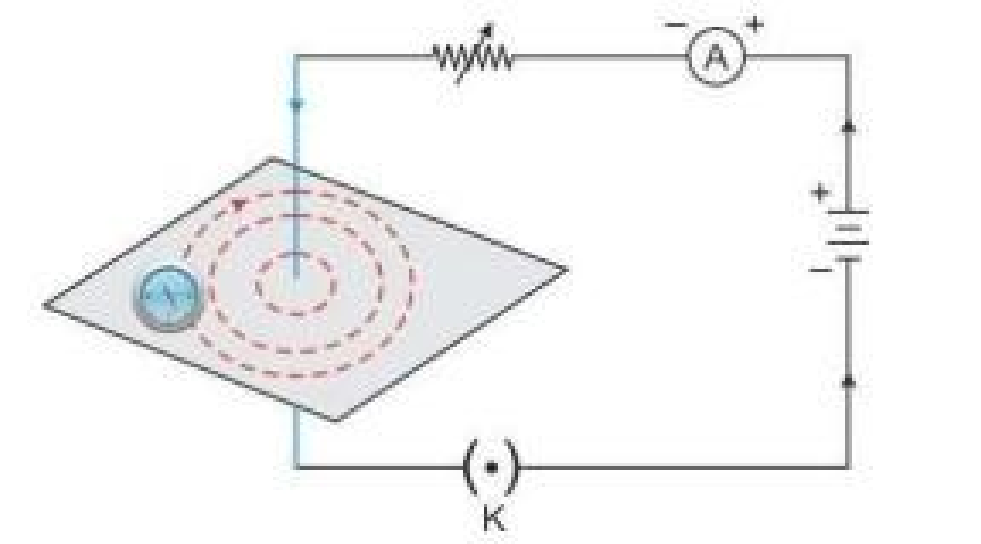
Magnetic Field due to a Straight Current-carrying Conductor

- The magnetic field lines around a straight conductor carrying a current are concentric circles.



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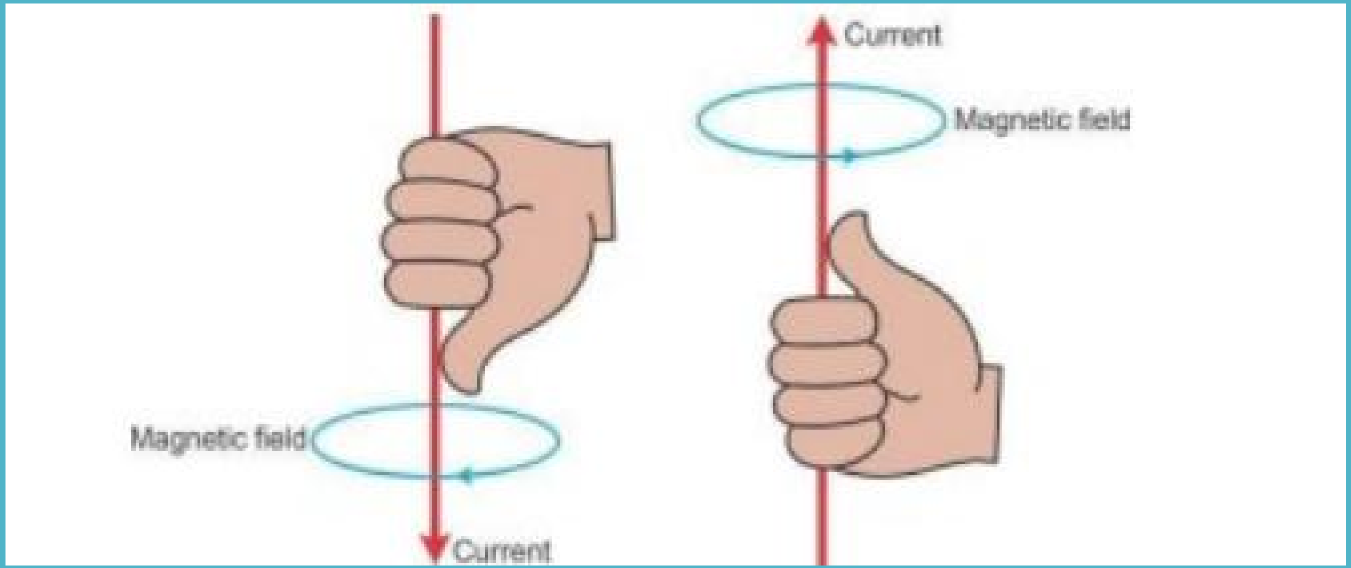
Magnetic Field due to a Straight Current-carrying Conductor

- The direction of a magnetic field is given by the Right-Hand Thumb Rule.



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Magnetic Field due to a Straight Current-carrying Conductor

Right-Hand Thumb Rule:

Imagine that you are holding a straight current-carrying conductor in your right hand such that the thumb points towards the direction of the current. Then, your curved fingers wrapped around the conductor point in the direction of the field lines of the magnetic field.

- The magnitude of the magnetic field due to a straight current-carrying conductor at a given point is

Directly proportional to the current flowing through the conductor

Inversely proportional to the distance of that point from the conductor

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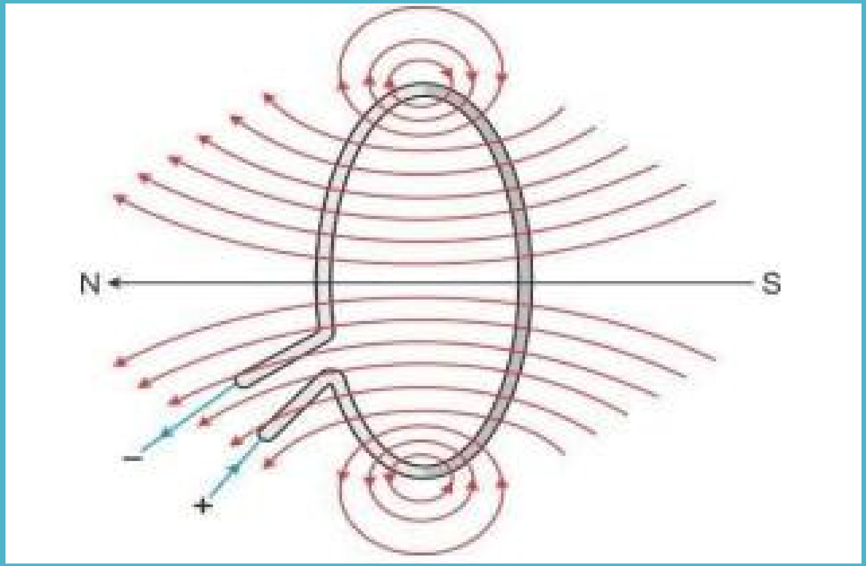
Magnetic Field due to a Current-carrying Circular Coil



- The magnetic field lines near the coil are nearly circular or concentric.
- The magnetic field at the centre of the coil is maximum and almost uniform.

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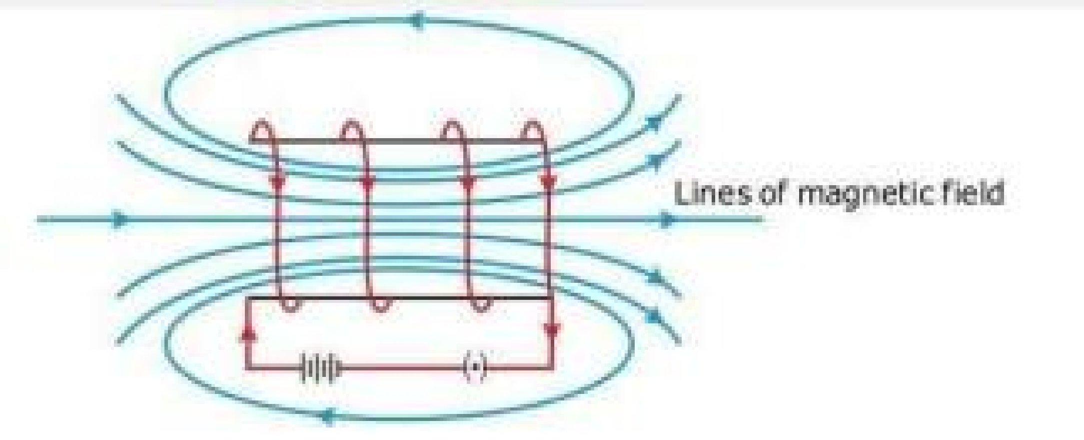
Magnetic Field due to a Current-carrying Solenoid

- The pattern of the magnetic field lines around a current-carrying solenoid is similar to that produced by a bar magnet as shown in the figure below.
- The magnetic field inside a solenoid is uniform.



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Magnetic Field due to a Current-carrying Solenoid

- In accordance with the Clock rule, the end of the solenoid at which the current flows in the anticlockwise direction behaves as a North Pole, while the end at which the current flows in the clockwise direction behaves as a South Pole.
- The magnitude of the magnetic field inside the solenoid is directly proportional to the
  - Current flowing through it
  - Number of turns per unit length of the solenoid

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Force on a Current-carrying Conductor in a Magnetic Field

- A current-carrying conductor when placed in a magnetic field experiences a force.
- The direction of the force gets reversed when the direction of the current is reversed or when the direction of the magnetic field is reversed.
- The force acting on a conductor is found to be maximum when the current and magnetic field are at right angles to each other.
- When the conductor is placed parallel to the magnetic field, no force acts on it.

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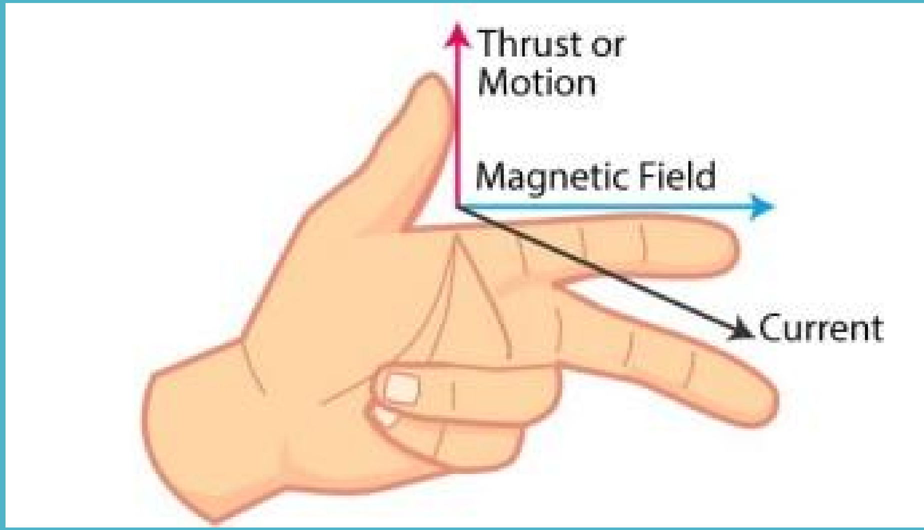
Force on a Current-carrying Conductor in a Magnetic Field

- **Fleming's Left-Hand Rule gives the direction of the magnetic force acting on the conductor.**



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Force on a Current-carrying Conductor in a Magnetic Field

Fleming's Left-Hand Rule:

Stretch the thumb, forefinger and middle finger of the left hand such that they are mutually perpendicular to each other. If the forefinger points in the direction of the field, and the middle finger in the direction of the current, then the thumb gives the direction of motion or the force acting on the conductor.

- The force experienced by a current-carrying conductor in a magnetic field is the underlying principle of an electric motor where electric energy is converted into mechanical energy. Such motors are used to run many electrical appliances, including fans, toys etc.

Chapter 4: Magnetic Effects of Electric Current

Electric motor

- An electric motor is a rotating device that converts electrical energy to mechanical energy.
- An electric motor consists of a rectangular coil ABCD of insulated copper wire. The coil is placed between the two poles of a magnetic field such that the arm AB and CD are perpendicular to the direction of the magnetic field.

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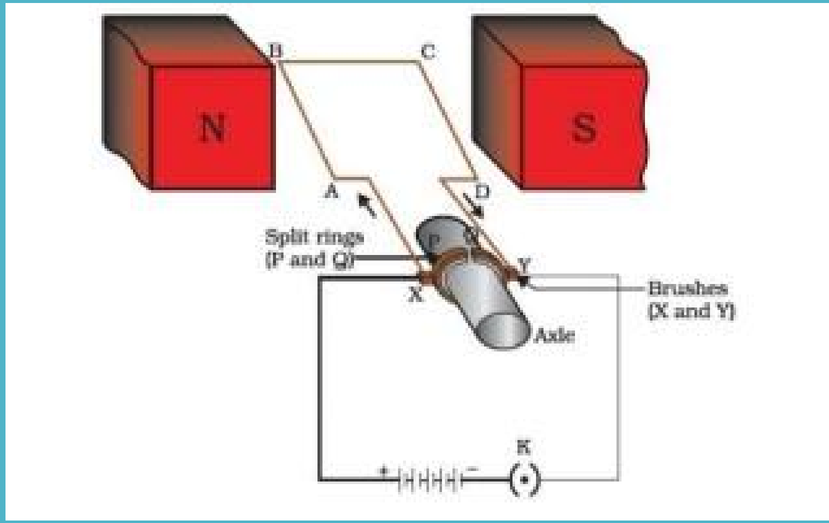
Electric motor



- The ends of the coil are connected to the two halves P and Q of a split ring. The inner sides of these halves are insulated and attached to an axle.
- The external conducting edges of P and Q touch two conducting stationary brushes X and Y, respectively.

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Electric motor

- Current in the coil ABCD enters from the source battery through conducting brush X and flows back to the battery through brush Y.
- The force acting on arm AB pushes it downwards while the force acting on arm CD pushes it upwards.
- Thus the coil and the axle O, mounted free to turn about an axis, rotate anti-clockwise.
- At half rotation, Q makes contact with the brush X and P with brush Y. Therefore the current in the coil gets reversed and flows along the path DCBA.

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Electric motor

- The split ring acts as a commutator which reverse the direction of current and also reverses the direction of force acting on the two arms AB and CD.
- Thus the arm AB of the coil that was earlier pushed down is now pushed up and the arm CD previously pushed up is now pushed down.
- Therefore the coil and the axle rotate half a turn more in the same direction. The reversing of the current is repeated at each half rotation, giving rise to a continuous rotation of the coil and to the axle.

Chapter 4: Magnetic Effects of Electric Current

Electric motor

- Commutator: A device that reverses the direction of flow of current through a circuit is called a commutator.
- Armature: The soft iron core, on which the coil is wound including the coils is called armature. It enhances the power of the motor.

Chapter 4: Magnetic Effects of Electric Current

Electromagnetic Induction (EMI)

- The phenomenon of generating an electric current in a circuit (coil) by changing the magnetic flux linked with it is called electromagnetic induction.
- The change in magnetic flux in a coil may be due to the

o Relative motion between the coil and the magnet placed near it.

o Relative motion between the coil and a current-carrying conductor placed near it

o Change of current in the conductor placed near the coil

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

Chapter 4: Magnetic Effects of Electric Current

Electromagnetic Induction (EMI)

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

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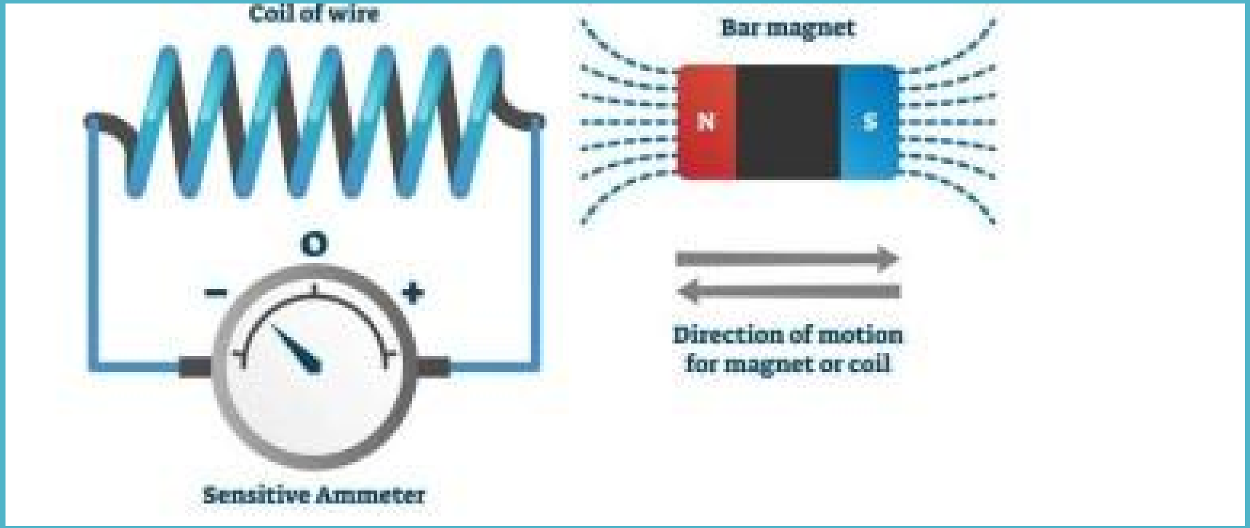
Faraday's law of Electromagnetic Induction



- First law: Whenever a conductor is placed in a varying magnetic field, EMF induces and this emf is called an induced emf and if the conductor is a closed circuit than the induced current flows through it.
- Second law: The magnitude of the induced EMF is equal to the rate of change of flux linkages.

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Faraday's law of Electromagnetic Induction

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

So now, the induced voltage is as follows:

$e = N \times d\Phi dt$

where,

e is the induced voltage

N is the number of turns in the coil

Φ is the magnetic flux

t is the time

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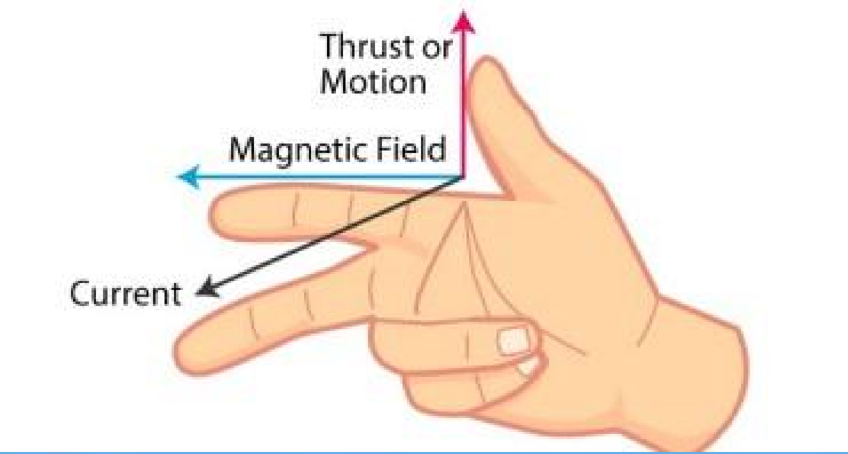
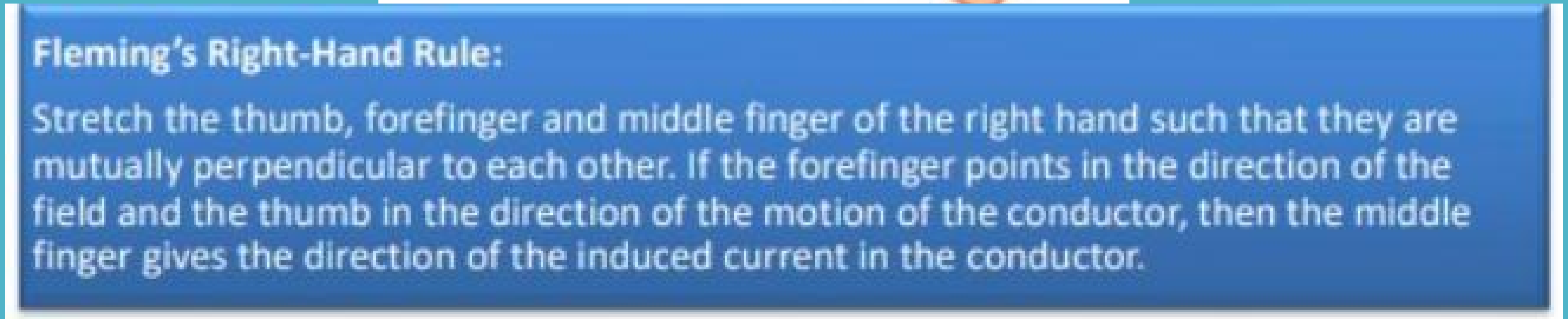
Faraday's law of Electromagnetic Induction

Fleming's Right-Hand Rule is used to find the direction of induced current.





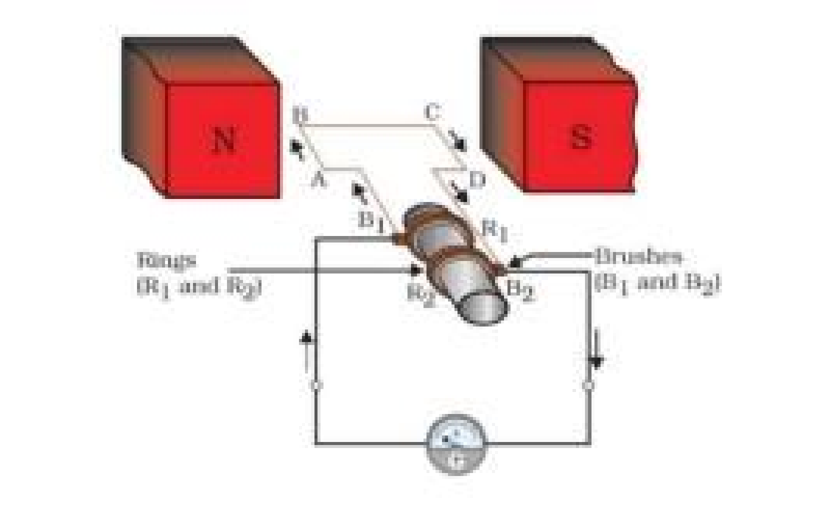
Fleming's Right-Hand Rule:

Stretch the thumb, forefinger and middle finger of the right hand such that they are mutually perpendicular to each other. If the forefinger points in the direction of the field and the thumb in the direction of the motion of the conductor, then the middle finger gives the direction of the induced current in the conductor.

Chapter 4: Magnetic Effects of Electric Current

Electric Generator

- An electric generator, mechanical energy is used to rotate a conductor in a magnetic field to produce electricity.
- An electric generator consists of a rotating rectangular coil ABCD placed between the two poles of a permanent magnet.



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Electric Generator

- The two ends of this coil are connected to the two rings R1 and R2. The inner side of these rings are made insulated.
- The inner side of these rings are made insulated. The two conducting stationary brushes B1 and B2 are kept pressed separately on the rings R1 and R2, respectively.
- The two rings R1 and R2 are internally attached to an axle. The axle may be mechanically rotated from outside to rotate the coil inside the magnetic field.
- Outer ends of the two brushes are connected to the galvanometer to show the flow of current in the given external circuit.

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Electric Generator

- When the axle attached to the two rings is rotated such that the arm AB moves up (and the arm CD moves down) in the magnetic field produced by the permanent magnet.
- After half a rotation, arm CD starts moving up and AB moving down. As a result, the directions of the induced currents in both the arms change, giving rise to the net induced current in the direction DCBA.
- The current in the external circuit now flows from B1 to B2. Thus after every half rotation the polarity of the current in the respective arms changes.

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Electric Generator

To get a direct current (DC), a split-ring type commutator must be used. With this arrangement, one brush is at all times in contact with the arm moving up in the field, while the other is in contact with the arm moving down.

The direct current always flows in one direction, whereas the alternating current reverses its direction periodically.

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Domestic Electric Circuits

- In our homes, we receive electric power through a main supply called the mains. We receive an AC electric power of 220 V with a frequency of 50 Hz.
- One of the wires in the electricity wiring of houses has a red insulation and is called the live wire. The other, of black insulation is called the neutral wire. The third is the earth wire which has green insulation and is connected to a metallic plate deep inside the Earth.

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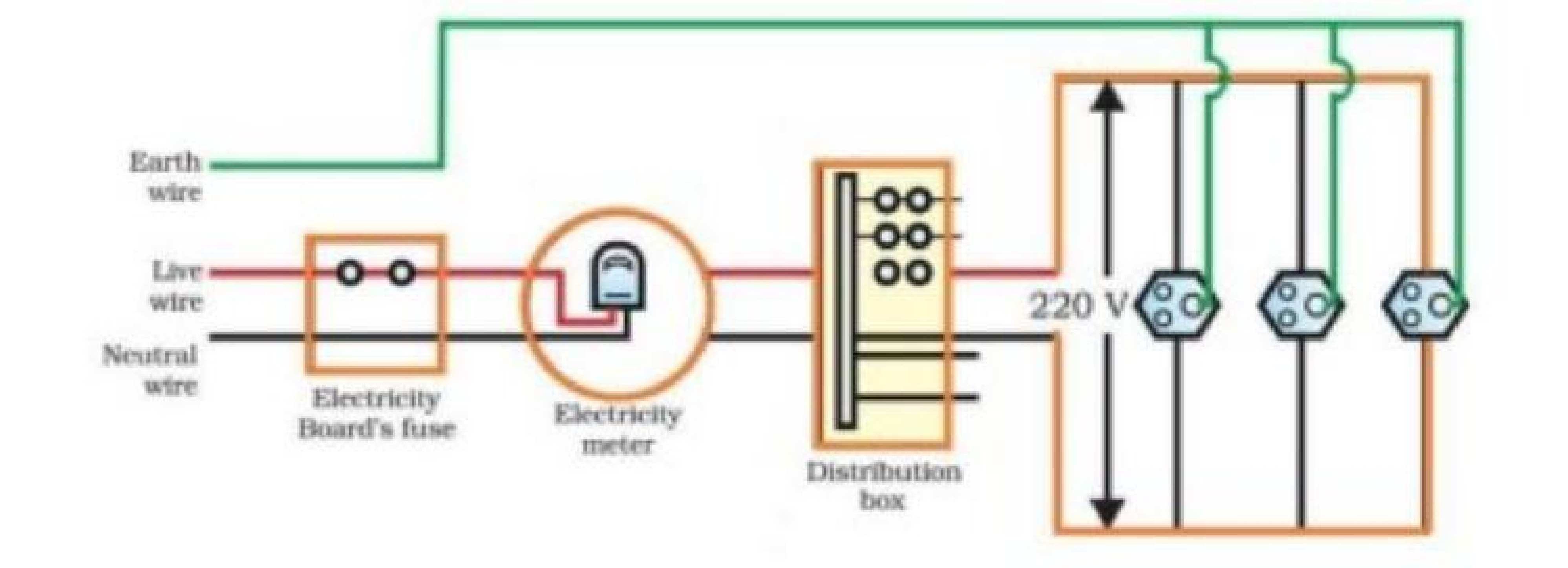
Domestic Electric Circuits



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Domestic Electric Circuits

The earth wire in wiring is used as a safety measure to ensure that any leakage of current in the metallic body does not give the user a severe shock.

A fuse is an important safety device used to protect circuits and appliances from shortcircuiting (which occurs when a live wire and a neutral wire come in contact) or overloading (which occurs when an electric circuit draws more current than the permitted value).

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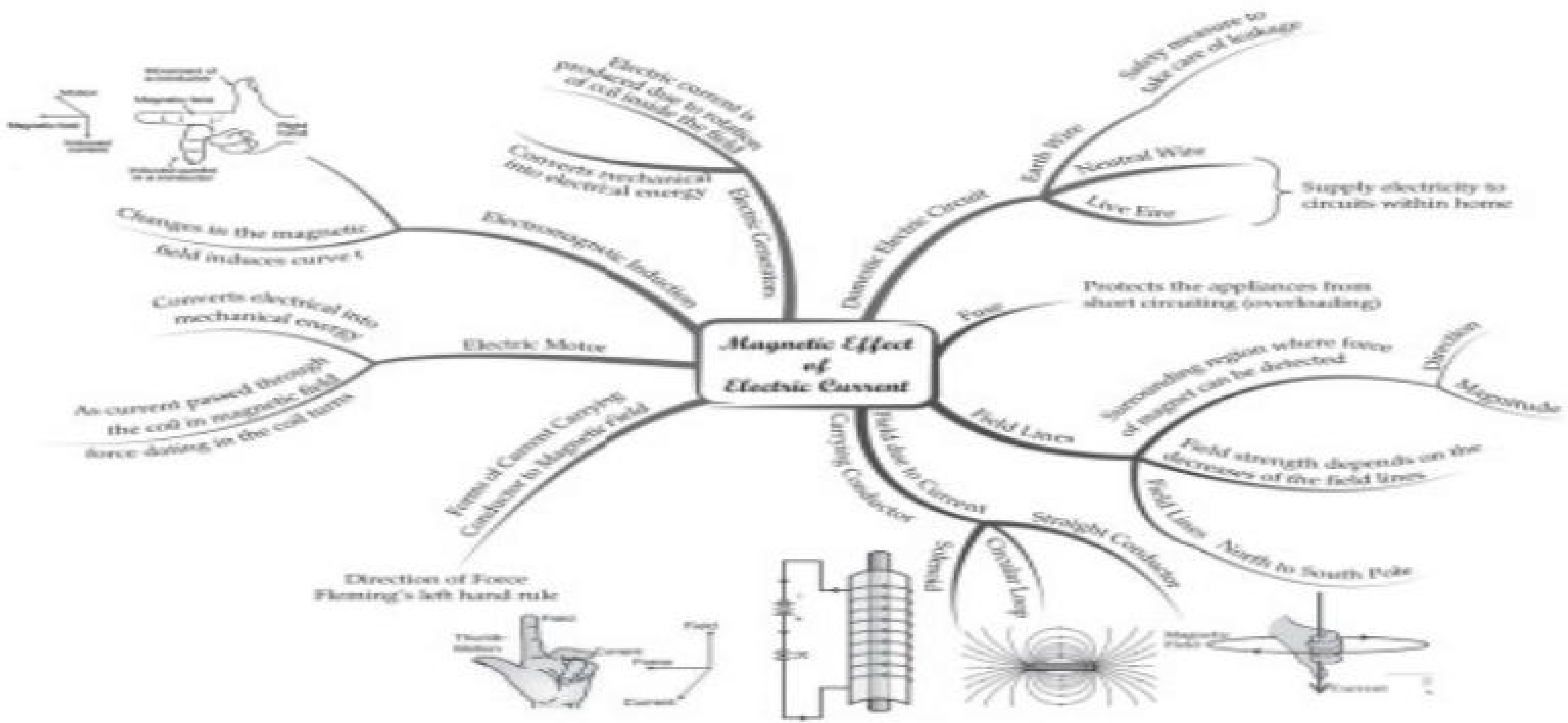
MIND MAP : LEARNING MADE SIMPLE

Chapter-13



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