Magnetism

A **magnet** is a substance which attracts other magnetic materials within its field. A **magnetic field** is the region within which another magnetic material encounters a force.

A **magnetic field line (or magnetic flux)** is the smallest unit of a magnetic field.

A magnet has 2 poles: a North and a South. No matter how many times a magnet is broken down, it will still have those two poles.

Like poles repel, while unlike poles attract. This means that two N poles or two S poles will repel, while one N pole and one S pole will attract.

There are two types of magnetic materials: **Soft** and **Hard**.
Soft magnetic materials are those whose magnetism is temporary and include iron. These are used in electric bells.

Hard magnetic materials are those whose magnetism is permanent and include steel. These are used in permanent bar magnets or horse-shoe magnets.

Magnetism maybe **induced** into a neutral magnetic material by bringing a magnetic pole close to a nail. If we bring a N pole close to the nail, it will induce magnetism in it by forming a S pole on the near side of the nail and a N pole on the furthest side, thus causing attraction. If another uncharged nail is brought close to the magnetized nail, the same thing happens. A S pole will be induced on the near side of the 2nd nail, causing the 2nd nail to attract to the 1st. This maybe repeated to form a chain of nails.

A **uniform magnetic field** maybe formed by placing the N pole of one magnet on top of the S pole of another magnet. Both the magnets need to be of the same strength. Once this is done, a field would be formed between the poles, where the lines would be of equal length and the lines would be equally spaced. 'Uniform' means 'equal' or 'constant' and the lines show that property.

The **magnetic field direction** is always from the North to the South. **The field line leaves the North Pole and enters the South Pole**. The Earth has a weak magnetic field of its own, and its geographical North is actually the magnetic South pole, and its geographical South is actually the magnetic North pole. In places where the poles attract, the field lines add up. In places where the poles repel, the field lines cancel each other out.

Electromagnetism

This topic helps us understand that magnetism maybe produced from electricity.

Whenever current flows through a wire, a magnetic field is produced around it.

The direction notations for the current direction through a wire are as follows:

Current going into the page is denoted by a cross (like when an arrow leaves us). Current coming out of the page is denoted by a dot (like when an arrow comes towards us). These notations are used in **the right-hand grip rule**. In this rule, the thumb represents the direction of the current, while the direction in which the fingers are curled around represents the direction of the magnetic field.

The right-hand grip rule is modified when we use a solenoid. The direction in which the fingers are curled around represent the current direction, while the thumb points towards the North pole of the magnet produced by the solenoid.

****LEARN THE MAGNETIC FIELD PATTERNS OF A STRAIGHT WIRE, CIRCULAR COIL OF WIRE AND SOLENOID FROM THE BOOK****

Electromagnetism makes use of the interaction between the field lines of two magnetic fields and is most prominently observed in **loudspeakers**. A permanent magnet is placed inside it, which produces a magnetic field, and the current flowing through the wire produces another magnetic field. When the fields interact, the field lines overlap, adding up where both the field directions are the same, and cancelling out in places where the field directions are opposite. This produces a force on the wire, causing the skin to move to and fro. This movement causes the air to be compressed and released, thus forming sound waves.

Moreover, whenever a charged particle flows perpendicularly to a magnetic field, a force is exerted on the particle. As we know, flow of charged particles is known as current, and this is very similar to current flowing in a wire. So, a magnetic field is also formed around the moving charged particle, and due to the overlapping of the field lines of the particle and the magnet, a force is applied on the particle. The particle has to flow perpendicularly as moving in parallel means there is no overlap of field lines.

The direction of the force may be determined by using **Fleming's Left Hand Rule.** In this rule, the thumb represents the force direction, the 1^{st} finger represents the field direction and the 2^{nd} finger represents the current direction. These fingers are placed perpendicularly to each other.

Electromagnetism is noticed in the **simple d.c. motor**. In this one, the coil is attached to the battery by the use of a pair of split rings, which are connected to a pair of carbon brushes. The carbon brushes act as insulators on the outside, but allow the conduction of current through the wire. The split rings move under the influence of the magnetic force (known as motor action), which causes them to move through 180 degrees. This causes the rings to interchange positions, and when this happens, the current directions reverse, thus reversing the force direction.

The size of the force may be increased by:

1. Increasing the current
2. Using a stronger magnet
3. Using a coil with more turns

Electric bells

When the switch is pressed, the circuit becomes complete and current starts flowing. This causes the soft iron core to become magnetized and this pulls the armature into place. The armature presses down on a part attached to the hammer, which then strikes the gong. When the switch is released, the current stops flowing and the iron core is no longer magnetized, meaning the hammer is no longer striking the gong.

Circuit breaker

When current above a certain limit flows through the circuit, it magnetizes the soft iron core and causes it to pull the armature out of place. When this happens, the circuit becomes incomplete and thus prevents any further flow of current through the circuit, protecting the appliance.

Electromagnetic Induction

In the previous segment, we learned that magnetism may be generated from electricity. In this segment, we will learn that electricity may be generated from magnetism, by the process of induction.

This may be achieved in two ways:

1. Keeping a magnet steady and moving a wire/coil across it
2. Keeping a coil steady and moving a magnet across it

1. The horse-shoe magnet has invisible field lines which are cut when the wire is moved perpendicularly across those lines. This causes a change of magnetic flux linkage, resulting in the induction of voltage across the wire. The amount of current may be increased by:
   (a) Moving the wire faster
   (b) Using a stronger magnet
   (c) Wrapping the wire into a coil

****DIAGRAMS IN THE BOOK****

2. The bar magnet has invisible field lines which are cut when the magnet is moved across the coil. This causes a change of magnetic flux linkage, resulting in the induction of voltage across the wire. The amount of current may be increased by:
   (a) Moving the magnet faster
   (b) Using a stronger magnet
   (c) Increasing the turns in the coil

****DIAGRAMS IN THE BOOK****

The direction of the current may be changed by pulling the magnet out of the coil, rather than pushing it in. When the North Pole is pushed in, it induces a North pole on the near side of the coil, causing a current flow in one way. When the North Pole is pulled out, it induces a South pole on the near side of the coil, causing the current to flow in the opposite way. The current direction may also be reversed by simply pushing in the South pole instead of the North pole.

The amount of voltage induced in the coil/wire may be determined by the use of **Faraday's Law of Electromagnetic Induction**:

The size of the induced voltage is directly proportional to the rate of change of magnetic flux linkage.

So, the greater the number of field lines cut per second, the greater is the size of the induced voltage.

The principle of induction is also known as the **generator action**.

A generator may be created by simply altering a few aspects of the simple d.c. motor. In the generator, a force has to be provided to get electricity. So, instead of the split rings, we use a pair of slip rings, connected to the output, via a pair of carbon brushes. Those output terminals will act as the positive and the negative terminals. (Previously, we had split rings connected to a battery). The movement of the coil across the magnetic field will result in the production of current.

A **transformer** is a device which is used to convert a smaller voltage to a larger one, or vice versa. It makes use of the generator principle. The transformer has **an input (primary) coil**, attached to an AC supply, and **an output (secondary) coil**, attached to electrical appliances. Both of these coils are wrapped around a soft iron core.

When current flows in the primary, it results in a magnetic field. The field lines of this magnetic field continuously cuts the secondary coil, resulting in a change of magnetic flux linkage, which causes induction of voltage in the secondary. The iron core's purpose is simply to concentrate the magnetic field lines of the primary, so that most of the flux comes in contact with the secondary.

There are two types of transformers:

1. Step-up (increases the voltage) (more turns in secondary than in primary)
2. Step-down (decreases the voltage) (more turns in primary than in secondary)

The relation between the no. of turns and the voltage may be given by:

Primary voltage/Secondary voltage = Turns in primary/Turns in secondary

$V_p/V_s = N_p/N_s$

Moreover, we assume that the transformer has 100% efficiency and so all of the input power is converted to output power.

$$P_{in} = P_{out}$$

$$V_pI_p = V_sI_s$$

When the voltage is transmitted from the power station to the transmission line, it is **stepped-up**. This is done so that the voltage increases, and to keep the power constant, the current has to decrease. Lesser current results in lesser amount of heat loss in the transmission line, meaning more efficiency.

When the voltage is transmitted from the transmission line to factories/homes, it is **stepped-down**. This is done so that the voltage decreases, and to keep the power constant, the current has to increase. This is necessary as the electrical appliances in homes/factories use a lot of current.