MAGNETS AND MAGNETIC FIELDS

A magnet is defined as any substance that can attract iron, nickel, cobalt steel and other metals

Magnetic Field Intensity (B)

The unit of magnetic field intensity is Tesla(T) or Ampere per meter (A/m)

MAGNETIC FLUX

This is the number of field lines that pass through a given surface.

$$\phi_B = \int_s \vec{B} \cdot \vec{dA}$$

If the magnetic field (intensity) is constant

$$\phi_B = \vec{B} \cdot \vec{A} = B A \cos\theta$$

%theta is the angle between the field and the normal to the surface

A is the area of the surface

%theta is also the angle between B and A whose direction is perpendicular to the face of the loop

The SI unit of flux is tesla metre squared (T{m^2}) or weber (Wb)

If B and A are parallel %theta = 0, $\phi_B = BA$

If they are opposite, $\phi_B = -BA$

If they are perpendicular, $\phi_B = 0$

TYPES OF MAGNETS

1. Natural Magnets: These are magnets made of the ores of iron (magnetite). They are found as huge deposits in the earth’s crust.
2. Artificial Magnets: These are the magnet made in the laboratory or industry. They are mainly made from iron or steel.

METHODS OF MAKING MAGNETS

1. Electrical Method: This is also called the solenoid method. In this method, a soft iron bar is placed in a wound coil (solenoid). A direct current is made to flow through it. The polarity of the magnet formed depends on the direction of flow of current. IF the current is flowing clockwise through one end, that end will be the south-pole but if anti-clockwise that end will be the north-pole.

2. Single touch method: In this method, the pole of a magnet is used for striking (the end of) a soft iron bar in a repeated manner. The end of the bar that is touched last will have opposite polarity to that of the end of the pole striking it.
3. Double touch method: This is similar to the single touch method. However, in this case, two opposite poles of two different magnets strike the opposite ends of a soft iron bar. As explained in the single touch, the ends will have opposite polarities to the polarities striking them.
4. Hammering in the earth's magnetic field: When a soft iron bar is placed in the direction of the earth's magnetic field and hammered repeatedly, a weak magnet will be formed

<u>DEMAGNETIZATION</u>

This is defined as the process through which magnets lose their magnetic properties. Ways of demagnetization include

1. Solenoid Method: In this method, an iron bar is placed in a wound coil and an alternating current is passed through it. After this, the magnet is withdrawn it in east-west direction to finally make it lose its magnetic properties.
2. Heating: The magnetic properties of a magnetic can be lost by heating the magnetic to red hot
3. Hammering: The magnetic properties of a magnet can be lost can be lost by heating the magnet in the east-west direction.

<u>PROPERTIES OF MAGNETS</u>

1. Suspension: When a bar magnet is suspended it will lie in a north-south direction. The end pointing upward is the north-pole while the end pointing downward is the south-pole. Any magnet has two ends or faces called poles where the magnetic effect is strongest. If a bar magnet is suspended from a fine thread, it is found that one of the magnet poles will always point toward the north. The north pole of the bar magnet is the pole that points towards the geographic north and the one that points towards the south is called the south pole.
2. Dipole Concept: When a magnet is broken into two, new opposite poles would be formed at the point would be formed at the point of breakage preventing the isolation of a single pole.

   From this, we know that no magnet has just one pole. A magnet must have two poles (A north-pole and a south-pole).

   It should be noted that even though opposite poles are formed at the point of breakage, those poles never attract (even if unlike poles attract).
3. Polarity concept: This concept shows that the strength of a magnet is at the poles of the magnet. When some iron filings or powders are sprinkled on a bar magnet, most of them will cling to the ends (or poles) of the magnet. This implies that the strength of a magnet lies at the poles of the magnet.

The pole of a magnet can therefore be defined as the region where magnetic field intensity is maximum.

4. Induced magnetism: When a pin is placed below a magnet, it becomes attached. The pin can further attract other pins giving rise to a magnetic chain. The length of the chain depends on the strength of the magnet. The stronger the magnet, the longer the length of the chain can be.

COMPARING THE MAGNETIC PROPERTIES OF IRON AND STEEL

1. Iron can easily be magnetized while it takes steel a longer time
2. Magnets made of iron can easily lose their magnetic properties while those made of steel can retain their properties over a longer period of time
3. Magnets made of iron are stronger than those made of steel
4. Iron is used to make temporary magnet while steel is used to make permanent magnets

TYPES OF MAGNETIC MATERIALS

The magnetic state (or magnetic phase) of a material depends on temperature, pressure and the applied magnetic field. A material may exhibit more than one form of magnetism as temperature, pressure and/or applied magnetic field change.

1. Ferromagnetic materials: These are materials that will increase greatly the magnetic strength of the region where they are subjected. Their relative permeability $\mu_o$is much higher than one. Examples include Iron, cobalt, nickel and steel etc.

$\mu_o \geqslant 1$

2. Diamagnetic materials: These are the materials that will reduce the magnetic field strength of the region where they are subjected slightly. Their relative permeability is slightly less than one.

$\mu_0 < 1$

Graphite, Bismuth and copper are popular examples of diamagnetic materials

3. Paramagnetic material: These are the materials that can increase slightly the magnetic field of the region where they are subjected. The relative permeability is slightly higher than one.

$$\mu_o > 1$$

Non magnetic substances are substances that are negligibly affected by a magnetic field. Examples include: copper, aluminum, gases and plastic

CONCEPT OF MAGNETIC FIELDS

Magnetic fields are regions where magnetic forces can be experienced. The direction of the magnetic field can be obtained from a compass needle. The magnetic lines of force always point away from the north and point in towards the south.

The closer the field lines, the stronger the field and these field lines do not cross each other as a result of repulsion.

Conventionally, unlike poles attract and like poles repel.

ELEMENTS OF EARTH'S MAGNETIC FIELD

1. Magnetic Meridian: This can be defined as a plain passing through the magnetic north and the magnetic south.
2. Geographic Meridian: This is defined as a vertical plain passing through the geographic north and the geographic south.
3. Angle of dip: This is also called the angle of inclination. This is defined as the angle between the magnetic north (meridian) and the horizontal. The angle of dip is 90 degrees at the (geographic) pole and zero degrees at the (geographic) equator. It is also defined as the angle between the direction of the earth's magnetic flux and the horizontal. The angle of dip is measured by an instrument called the dip circle.
   The range of dip is from -90 degrees (at the south pole) to 90 degrees at the north pole
4. Angle of declination: This is called angle of variation. This is defined as the angle between the magnetic meridian and the geographic meridian. It can also be defined as the angle between the magnetic north and the geographic north. This angle of declination is widely used in navigation.

FORCE ON A MOVING CHARGE IN A MAGNETIC FIELD

A magnetic field exists in region of space if a moving charge there experiences a force (other than frictional force) due to its motion.

A moving charge will experience a force in a magnetic field. The magnitude of the force experienced depends on

1. Magnitude of the charge

$$F \propto q$$

2. Velocity of the moving charge

$$F \propto v$$

3. Strength of the magnetic field

$$F \propto B$$

4. Direction of the motion of the charge

$$F \propto \sin\theta$$

The magnitude of the force is maximum if the charge is moving perpendicularly to the field

$$F \propto qvB\sin\theta$$

$$F = kqvB\sin\theta$$

Taking $k=1$

$$F = qvB\sin\theta$$

At maximum force,

$$\theta = 90°$$

$$F = qvB\sin 90°$$

$$F_{max} = qvB \times 1$$

$$F_{max} = qvB$$

Here, B is the magnetic field intensity or magnetic strength. Its unit is the Tesla(T), Weber per square meter$(Wb\,m^{-2})$ or Goss(G)

$$1\,T = 1\,Wb\,m^{-2}$$

$$1\,G = 10^{-4}\,T$$

The direction of force on the moving charge can be obtained by using the right hand grip rule which states:

Hold the right hand flat and point the fingers in the direction of the field. Orient the thumb along the direction of the velocity (or the motion) of the (positive) charge then the palm of the hand pushes in the direction of the charge. The direction of the force is reversed for negative charges.

The centripetal force needed for the circular path is provided by the magnetic force, Thus

qvB = {{m{v^2}} over r}

r = mv over qB

{%omega} = v over r = qB over m

$$T = \frac{2\pi}{\omega} = \frac{2\pi m}{qB}$$

$$f = \frac{1}{T}$$

<u>MAGNETIC EFFECT OF CURRENT</u>

When a compass needle is placed beside a current carrying conductor, the needle is observed to be deflecting. This implies a current carrying will have a magnetic field around it.

According to Hans Oesterd, the magnetic field around the conductor is in a concentric (or circular) manner.

Depending on the type of conductor, the magnetic field intensity can be expressed in different ways

1. For a long straight wire: Oersted discovered that a current carrying wire (conductor) will have a magnetic field around it. This field is in a concentric manner and the magnetic field intensity (B) can be expressed as

$$B=\frac{\mu_o I}{2\pi d}$$

Here, d id the distance between the point (in consideration) and wire (or conductor)

2. For a solenoid: The magnetic field intensity is expressed as

$$B=\mu_o \ni$$

Here, N is the number of loops in the solenoid and “I” is the current passing through the solenoid.

3. Toroid:

$$B=\mu_o \ni \frac{\square}{2\pi d}$$

4. For a circular coil:

$$B=\mu_o \ni \frac{\square}{2r}$$

Here, r is the radius of the circular coil.

The direction of the magnetic field around a current carrying conductor (wire) can also be obtained from the right hand grip rule or the Maxwell corkscrew rule. Here this states

When a current carrying conductor is gripped with the right hand and the thumb extends in the direction of the current, the remaining four fingers point in the direction of the field (in a concentric form).

FORCE ON A CURRENT CARRYING CONDUCTOR IN A MAGNETIC FIELD

Hans Christian Oersted (1777 – 1851) found the connection between electricity and magnetism. He discovered that a compass needle placed near a current-carrying wire will deflect as long as current is flowing through the wire. Since a compass needle is deflected by a magnetic field, he concluded that the electric current produces a magnetic field. We can use the right hand grip rule to remember the direction of the magnetic field.

When we grab a wire, the thumb points in the direction of the current and our hands wrap around the wire show the concentric direction of the field.

A current carrying conductor will experience a force when placed in a magnetic field.

The force depends on

1. Strength of the magnetic field

$$F \propto B$$

2. Current passing through it:

$$F \propto I$$

3. Length of the conductor

$$F \propto l$$

4. Direction of the conductor (Angle between the conductor and the field): Maximum force is experienced when the conductor is placed perpendicularly to the field and no force is experienced when the conductor is placed parallel (or in the same direction) as the field.

$$F \propto \sin\theta$$

$$F \propto BIl\sin\theta$$

$$F = kBIl\,sin\theta$$

Taking k as 1

$$F = BIl\sin\theta$$

At maximum force,

$$\theta = 90°$$

$$F = BIl\sin 90°$$

$$F = BIl \times 1$$

$$F_{max} = BIl$$

Also to prove,

$$F = qvB\sin 90°$$

$$q = It$$

$$v = \frac{d}{t}$$

But for this case,

$$v = \frac{l}{t}$$

$$F = It \times \frac{l}{t} \times B \times \sin\theta$$

$$F = BIl\sin\theta$$

Cyclotron: This is used to accelerate charged particles such as protons, deutrons and helium nuclei to a high speed. These high speed particles produced are used to bombard atomic nuclei and thereby produce nuclear reactions.