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BTU 1113 Physics

Chapter 8: Magnetism

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Chapter Description

- Aims
  - Differentiate magnets and magnetic fields.
  - Measures magnetic force on electric current, moving charge particles and current carrying wire.

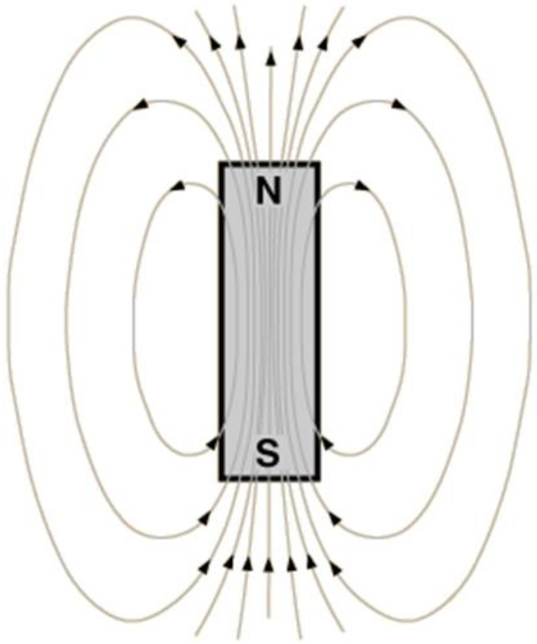
- Expected Outcomes
  - Students should be able to differentiate magnets and magnetic fields.
  - Students should be able to measures magnetic force on electric current, moving charge particles and current carrying wire.

- References

  - Giancoli, D.C., 2008. Physics for Scientists & Engineers. 4th edition. Prentice Hall, USA.
  - Jones, E., 2002. Contemporary College Physics. 3rd Ed, McGraw-Hill, Singapore.
  - Young, H. D. and Freedman, R. A., 2012. University Physics with Modern Physics. 13th edition, Pearson, San Francisco

1st aim:
Differentiate magnets and magnetic fields.

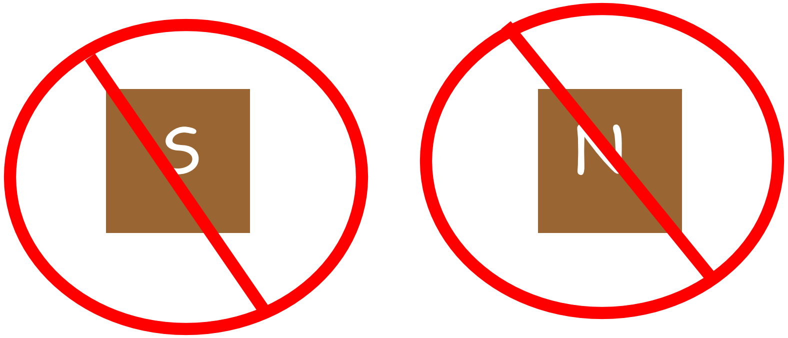
Facts about Magnetism



- Magnets have 2 poles (north and south)
- Like poles repel
- Unlike poles attract
- Magnets create a MAGNETIC FIELD around them

No Monopoles Allowed

It has not been shown to be possible to end up with a single North pole or a single South pole, which is a monopole ("mono" means one or single, thus one pole).



Note: Some theorists believe that magnetic monopoles may have been made in the early Universe. So far, none have been detected.

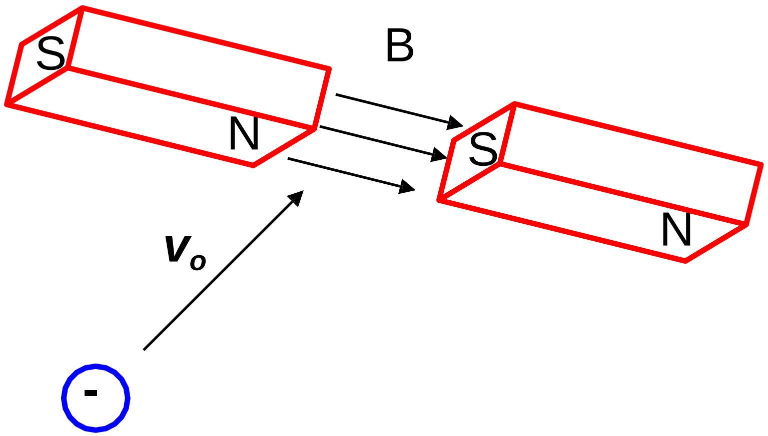
Magnetic Field

A bar magnet has a magnetic field around it. This field is 3D in nature and often represented by lines LEAVING north and ENTERING south

To define a magnetic field you need to understand the MAGNITUDE and DIRECTION

We sometimes call the magnetic field a B-Field as the letter "B" is the SYMBOL for a magnetic field with the TESLA (T) as the unit.

Magnetic Force on a moving charge



If a MOVING CHARGE moves into a magnetic field it will experience a MAGNETIC FORCE. This deflection is 3D in nature.

$$\vec{F}_B = q\vec{v} \otimes \vec{B}$$

$$F_B = qvB\sin\theta$$

The conditions for the force are:

- Must have a magnetic field present
- Charge must be moving
- Charge must be positive or negative
- Charge must be moving **PERPENDICULAR** to the field.

Magnets Have Magnetic Fields

We will say that a moving charge sets up in the space around it a magnetic field, it is the magnetic field which exerts a force on any other charge moving through it.

Magnetic fields are vector quantities....that is, they have a magnitude and a direction!

Defining Magnetic Field Direction

Magnetic Field vectors as written as $\vec{B}$

Direction of magnetic field at any point is defined as the direction of motion of a charged particle on which the magnetic field would <u>not</u> exert a force.

Magnitude of the B-vector is proportional to the force acting on the moving charge, magnitude of the moving charge, the magnitude of its velocity, and the angle between v and the B-field. Unit is the Tesla or the Gauss (1 T = 10,000 G).

The Concept of “Fields”

Michael Faraday realized that ...

A magnet has a ‘magnetic field’ distributed throughout the surrounding space

Magnetic Field Lines

Magnetic field lines describe the structure of magnetic fields in three dimensions.They are defined as follows. If at any point on such a line we place an ideal compass needle, free to turn in any direction (unlike the usual compass needle, which stays horizontal) then the needle will always point **along** the field line.

Field lines converge where the magnetic force is **strong**, and spread out where it is weak. For instance, in a compact bar magnet or "**dipole**," field lines spread out from one **pole** and converge towards the other, and of course, the magnetic force is strongest near the poles where they come together.

Action at a Distance Explained

Although two magnets may not be touching, they still interact through their magnetic fields.

This explains the 'action at a distance', say of a compass.

2nd aim:
Measures magnetic force on electric current, moving charge particles and current carrying wire.

Magnetism is the properties and interactions of magnets

The earliest magnets were found naturally in the mineral *magnetite* which is abundant the rock-type *lodestone*. These magnets were used by the ancient peoples as compasses to guide sailing vessels.

Magnets produce magnetic forces and have magnetic field lines

What are *magnetic* domains?

Magnetic substances like iron, cobalt, and nickel are composed of small areas where the groups of atoms are aligned like the poles of a magnet. These regions are called domains. All of the domains of a magnetic substance tend to align themselves in the same direction when placed in a magnetic field. These domains are typically composed of billions of atoms.

What is an *electromagnet*?

When an electric current is passed through a coil of wire wrapped around a metal core, a very strong magnetic field is produced. This is called an *electromagnet*.

What is a galvanometer?

A galvanometer is an electromagnet that interacts with a permanent magnet. The stronger the electric current passing through the electromagnet, the more is interacts with the permanent magnet.

Galvanometers are used as gauges in cars and many other applications.

The greater the current passing through the wires, the stronger the galvanometer interacts with the permanent magnet.

Direct current versus alternating current –

AC vs DC : What's the difference?

$Direct\ current$ is electrical current which comes from a battery which supplies a constant flow of electricity in one direction.

$Alternating\ current$ is electrical current which comes from a generator. As the electromagnet is rotated in the permanent magnet the direction of the current *alternates* once for every revolution.

Example

A proton moves with a speed of $1.0x10^5$ m/s through the Earth's magnetic field, which has a value of 55μT at a particular location. When the proton moves eastward, the magnetic force is a maximum, and when it moves northward, no magnetic force acts upon it. What is the magnitude and direction of the magnetic force acting on the proton?

$$F_B = qvB, \theta = 90, \sin 90 = 1$$

$$F_B = (1.6x10^{-19})(1.0x10^5)(55x10^{-6})$$

$$F_B = \mathbf{8.8x10^{-19}\ N}$$

The direction cannot be determined precisely by the given information. Since no force acts on the proton when it moves northward (meaning the angle is equal to ZERO), we can infer that the magnetic field must either go northward or southward.

Direction of the magnetic force?

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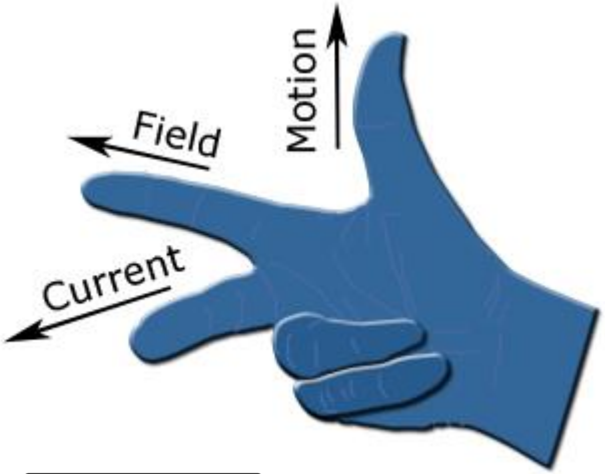
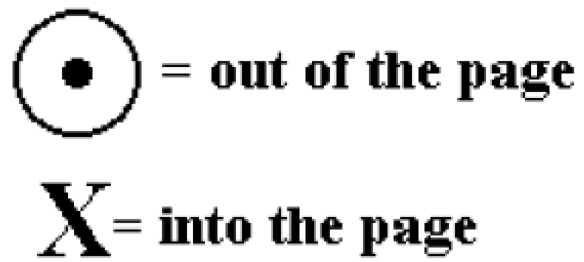
Right Hand Rule



Basically you hold your right hand flat with your thumb perpendicular to the rest of your fingers

To determine the DIRECTION of the force on a **POSITIVE** charge we use a special technique that helps us understand the 3D/perpendicular nature of magnetic fields.



- The Fingers = Direction B-Field
- The Thumb = Direction of velocity
- The Palm = Direction of the Force

For **NEGATIVE** charges use left hand!

Magnetic Force and Circular Motion

$$F_B = qvB,\ F_c = \frac{mv^2}{r},\ F_B = F_c$$

$$qvB = \frac{mv^2}{r}$$

$$r = \frac{mv}{qB}$$

The magnetic force is equal to the centripetal force and thus can be used to solve for the circular path. Or, if the radius is known, could be used to solve for the MASS of the ion. This could be used to determine the material of the object.

There are many "other" types of forces that can be set equal to the magnetic force.

$$F_B = qvB$$

$$mg = qvB$$

$$ma = qvB$$

Example

A singly charged positive ion has a mass of 2.5 x 10⁻²⁶ kg. After being accelerated through a potential difference of 250 V, the ion enters a magnetic field of 0.5 T, in a direction perpendicular to the field. Calculate the radius of the path of the ion in the field.

$$q = 1.6x10^{-19}C$$

$$m = 2.5x10^{-26}kg$$

$$\Delta V = 250V$$

$$B = 0.5T$$

$$r = ?$$

$$F_B = F_c \quad qvB = \frac{mv^2}{r} \quad r = \frac{mv}{qB}$$

We need to solve for the velocity!

$$\Delta V = \frac{W}{q} = \frac{\Delta K}{q} = \frac{1/2 mv^2}{q}$$

$$v = \sqrt{\frac{2\Delta Vq}{m}} = \sqrt{\frac{2(250)(1.6x10^{-19})}{2.5x10^{-26}}} =$$ **56,568 m/s**

$$r = \frac{(2.5x10^{-26})(56{,}568)}{(1.6x10^{-19})(0.5)} =$$ **0.0177 m**

Charges moving in a wire

Up to this point we have focused our attention on PARTICLES or CHARGES only. The charges could be moving together in a wire. Thus, if the wire had a CURRENT (moving charges), it too will experience a force when placed in a magnetic field.

Charges moving in a wire

$$F_B = qvB\sin\theta \times \frac{t}{t}$$

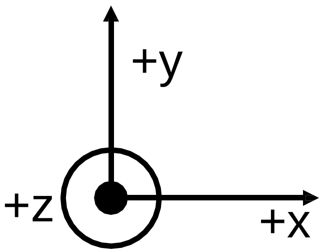
$$F_B = (\frac{q}{t})(vt)B\sin\theta$$

$$F_B = ILB\sin\theta$$

At this point it is VERY important that you understand that the MAGNETIC FIELD is being produced by some **EXTERNAL AGENT**

Example

A 36-m length wire carries a current of 22A running from right to left. Calculate the magnitude and direction of the magnetic force acting on the wire if it is placed in a magnetic field with a magnitude of 0.50×10^{-4} T and directed up the page.



B = +y

I = -x

F = **-z, into the page**

$$F_B = ILB\sin\theta$$

$$F_B = (22)(36)(0.50x10^{-4})\sin 90$$

$F_B =$ **0.0396 N**

The MAGNITUDE of the internal field

The magnetic field, B, is directly proportional to the current, I, and inversely proportional to the circumference.

$$B \alpha I \qquad B \alpha \frac{1}{2\pi r}$$

$$B \alpha \frac{I}{2\pi r}$$

$$\mu_o = \text{constant of proportionality}$$

$$\mu_o = \text{vacuum permeability constant}$$

$$\mu_o = 4\pi x 10^{-7} (1.26 x 10^{-6}) \frac{Tm}{A}$$

$$B_{\text{internal}} = \frac{\mu_o I}{2\pi r}$$

Example

A long, straight wires carries a current of 5.00 A. At one instant, a proton, 4 mm from the wire travels at 1500 m/s parallel to the wire and in the same direction as the current. Find the **magnitude** and **direction** of the magnetic force acting on the proton due to the field caused by the current carrying wire.

$$F_B = qvB_{EX} \qquad B_{IN} = \frac{\mu_o I}{2\pi r}$$

$$B_{IN} = \frac{(1.26x10^{-6})(5)}{2(3.14)(0.004)} = \mathbf{2.51 \times 10^{-4}\ T}$$

B = +z

v = +y

F = **-x**

$$F_B = (1.6x10^{-19})(1500)(B_{wire}) =$$

6.02 x 10^{-20} N

Conclusion of The Chapter

- Electricity and magnetism were initially thought to be separate phenomena. However, they are now considered so inseparable that they are now treated in combination as electromagnetism
- Magnetic forces are fundamental forces that arise from the movement of electrical charge
- Thus, magnetism is seen whenever electrically charged particles are in motion.
- This can arise either from movement of electrons in an electric current resulting in "electromagnetism"

Reference

Giancoli, D.C., 2008. Physics for Scientists & Engineers. 4th edition. Prentice Hall, USA.