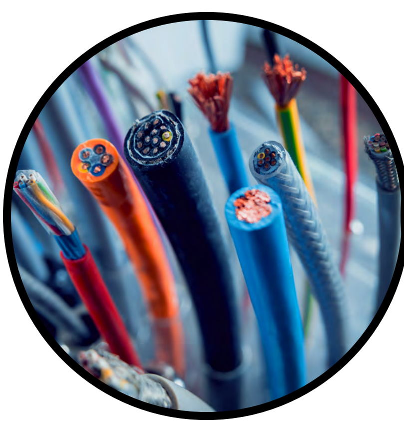
AIRCRAFT TECHNICAL BOOK COMPANY

B1/B2

AVIATION MAINTENANCE TECHNICIAN CERTIFICATION SERIES

ELECTRICAL FUNDAMENTALS

3



COMPLIANT WITH EASA

EASA PART 66/147

EASA 2023-989 COMPLIANT

Update notices for this book will be available online at www.actechbooks.com/revisions.html
If you would like to be notified when changes occur, please join our mailing list at www.actechbooks.com

VERSION	EFFECTIVE DATE	DESCRIPTION OF REVISION(S)
001	2014.08	Module creation and release.
002	2016.10	Format Updates
003	2017.03	Content updates and subject clarification.
004	2019.07	Fine tuned Submodule content sequence based on Appendix-A. Updated layout and styling.
004.1	2020.06	Corrected equations on parallel AC circuits and resonance, page 14.5 and 14.7.
004.2	2023.04	Inclusion of Measurement Standards for clarification, page iv. Minor appearance and format updates.
005	2024.04	Regulatory update for EASA 2023-989 compliance.

Module was reorganized based upon the EASA 2023-989 subject criteria. Enhancements included in this version 005 are:

3.5 *Sources of DC electricity* - Enhanced lithium cells content; added nickel cells.
3.7 *Resistance/Resistor*- Added resistor stability and tolerance; construction of potentiometers and rheostats.
3.9 *Capacitance/Capacitor* - Added plates in a capacitor.
3.11 *Inductance/Inductor*- Added position of inductance coils; plates in a capacitor.
3.13 *AC Theory* - Added opposition to AC current flow.
Additional minor non-regulatory adjustments throughout.

ELECTRICAL FUNDAMENTALS

TABLE OF CONTENTS

TABLE OF CONTENTS

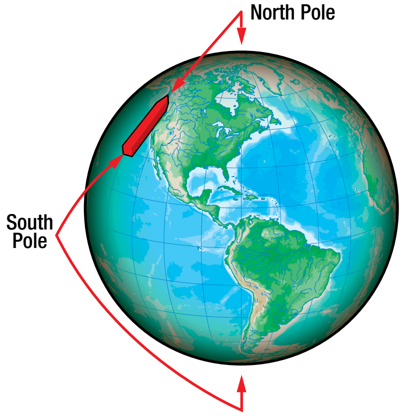


Figure 10-1. One end of the magnetized strip points to the magnetic north pole.

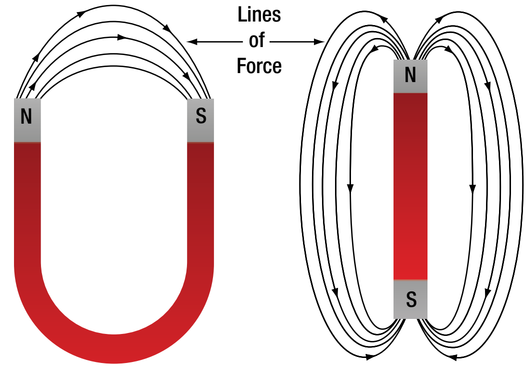


Figure 10-2. Magnetic field around magnets.

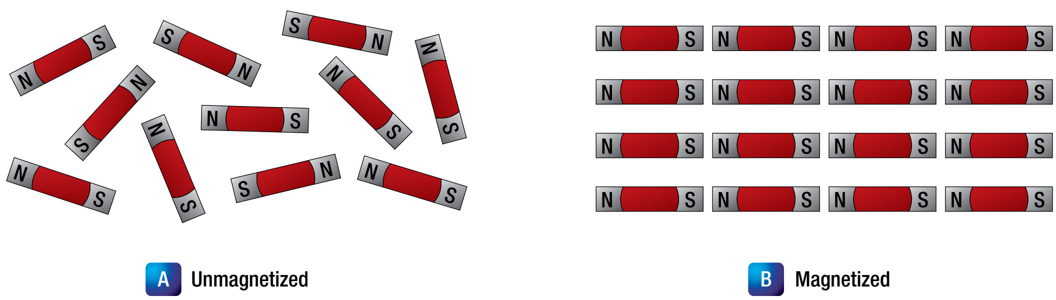


Figure 10-3. Arrangement of molecules in a piece of magnetic material.

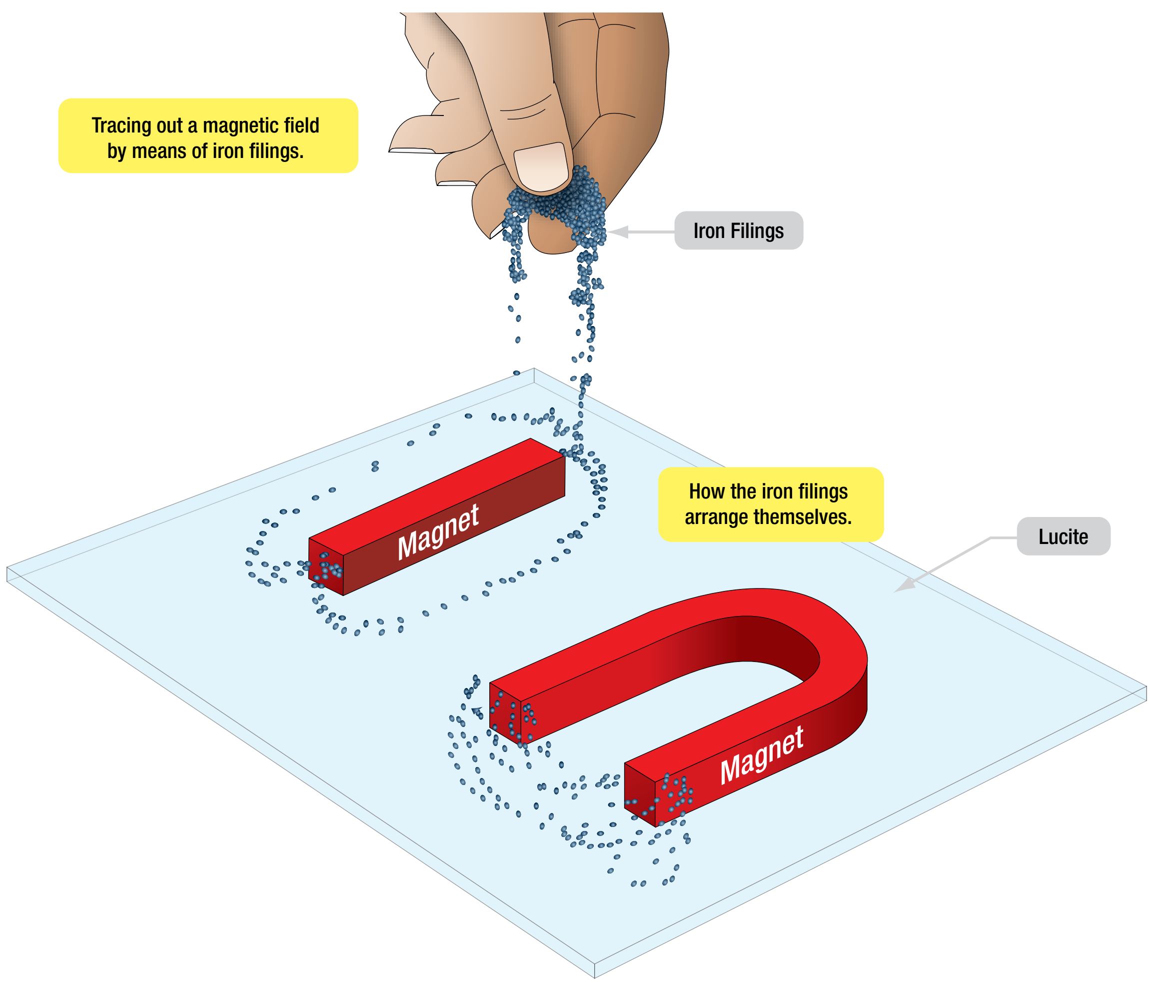


Figure 10-4. Tracing out a magnetic field with iron filings.

is used to describe the individual nature of the separate forces making up the entire magnetic field. These lines of force are also referred to as magnetic flux.

They are separate and individual forces, since one line will never cross another; indeed, they actually repel one another. They remain parallel to one another and resemble stretched rubber bands, since they are held in place around the bar by the internal magnetizing force of the magnet.

The demonstration with iron filings further shows that the magnetic field of a magnet is concentrated at the ends of the magnet. These areas of concentrated flux are called the north and south poles of the magnet. There is a limit to the number of lines of force that can be crowded into a magnet of a given size. When a magnetizing force is applied to a piece of magnetic material, a point is reached where no more lines of force can be induced or introduced. The material is then said to be saturated.

The characteristics of the magnetic flux can be demonstrated by tracing the flux patterns of two bar magnets with like poles together, as shown in **Figure 10-5**. The two like poles repel one another because the lines of force will not cross each other. As the arrows on the individual lines indicate, the lines turn aside as the two like poles are brought near each other and travel in a path parallel to each other. Lines moving in this manner repel each other, causing the magnets as a whole to repel each other. By reversing the position of one of the magnets, the attraction of unlike poles can be demonstrated, as shown in **Figure 10-6**.

As the unlike poles are brought near each other, the lines of force rearrange their paths and most of the flux leaving the north pole of one magnet enters the south pole of the other. The tendency of lines of force to repel each other is indicated by the bulging of the flux in the air gap between the two magnets. To further demonstrate that lines of force will not cross one another, a bar magnet and a horseshoe magnet can be positioned to display a magnetic field similar to that of **Figure 10-7**. The magnetic fields of the two magnets do not combine, but are rearranged into a distorted flux pattern.

The two bar magnets may be held in the hands and the north poles brought near each other to demonstrate the force of repulsion between like poles. In a similar manner, the two south poles can demonstrate this force. The force of attraction between unlike poles can be felt by bringing a south and a north end together. These experiments are illustrated in **Figure 10-8**.

Figure 10-9 illustrates another characteristic of magnets. If the bar magnet is cut or broken into pieces, each piece immediately becomes a magnet itself, with a north and south pole. This feature supports the theory that each molecule is a magnet, since each successive division of the magnet produces still more magnets.

Since the magnetic lines of force form a continuous loop, they form a magnetic circuit. It is impossible to say where in the magnet they originate or start. Arbitrarily, it is assumed that all lines of force leave the north pole of any magnet and enter at the south pole.

Reluctance, the measure of opposition to the lines of force through a material, can be compared to the resistance of an electrical circuit. The reluctance of soft iron, for instance, is much lower than that

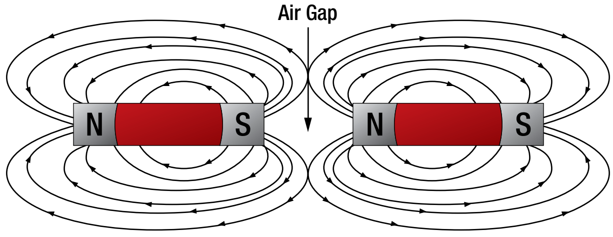


Figure 10-5. Like poles repel.

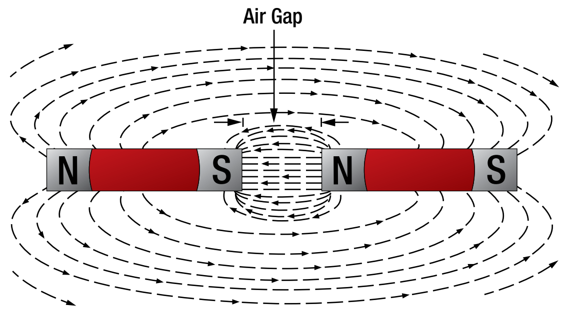


Figure 10-6. Unlike poles attract.

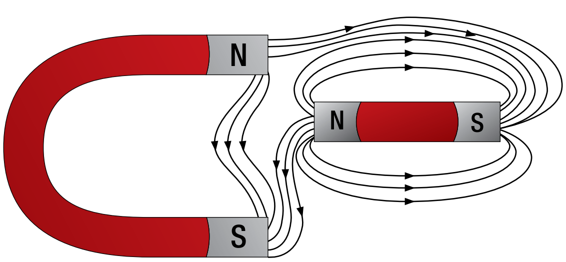


Figure 10-7. Bypassing flux lines.

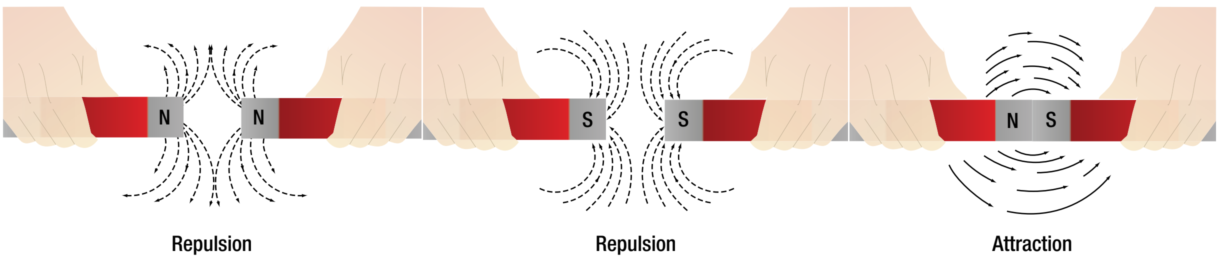


Figure 10-8. Repulsion and attraction of magnet poles.

of air. **Figure 10-10** demonstrates that a piece of soft iron placed near the field of a magnet can distort the lines of force, which follow the path of lowest reluctance through the soft iron.

The magnetic circuit can be compared in many respects to an electrical circuit. The magnetomotive force, causing lines of force in the magnetic circuit, can be compared to the electromotive force or electrical pressure of an electrical circuit. The magnetomotive force is measured in gilberts, symbolized by the capital letter 'F'. The symbol for the intensity of the lines of force, or flux, is the Greek letter phi, and the unit of field intensity is the gauss. An individual line of force, called a maxwell, in an area of one square centimeter produces a field intensity of one gauss. Using reluctance rather than permeability, the law for magnetic circuits can be stated: a magnetomotive force of one gilbert will cause one maxwell, or line of force, to be set up in a material when the reluctance of the material is one.

ACTION OF A MAGNET SUSPENDED IN THE EARTH'S MAGNETIC FIELD

A freely suspended magnet always points in the North-South direction even in the absence of any other magnet. This suggests that the Earth itself behaves as a magnet which causes a freely suspended magnet (compass needle) to point always in a particular direction: North and South. The shape of the Earth's magnetic field resembles that of a bar magnet of a length of 20% of the Earth's diameter buried at its center. [**Figure 10-11**]

MAGNETISM AND DEMAGNETIZATION

Remagnetizing a magnet is often necessary if the magnet has been mistreated. There are also often needs to make a tool magnetic to perform a desired function. Sometimes tools may inadvertently become magnetic with unwanted consequences and there is a need for demagnetization.

There are a few methods of magnetizing of an object which is made of the right type of ferrous material. To test suitability of a material you wish to magnetize, bring it in close proximity to a strong magnet. Then use the magnetized item to pick up iron filings or paper clips or other suitable object. If, after removing the magnet for a few minutes, there is little adhering, it will not be useful as a permanent magnet.

MAGNETIZATION BY HAMMERING

Hammering a rod will cause it to become slightly magnetic if laid along a magnetic field (North-South) or demagnetize it if laid across the field lines (East-West). Do not try to improve an existing magnet by hammering. Hammering could easily reduce the field strength below that already present.

MAGNETIZATION BY STROKING

There are two methods of magnetization by stroking; single touch and divided touch. With single touch, a magnet is drawn over the rod completely over its length. Magnetic lines are then pulled into alignment as the magnet passes. The best results are obtained after about twenty passes with the magnet taken in a big loop far away from the bar in between passes.

The divided touch method uses two magnets at the same time in what may be thought of as a mirroring action. This method produces a stronger magnet than with single touch. Beware of polarity: If this method is done using two similar poles facing the bar it is possible to create a magnet with two like poles at either end. These are termed consequent poles. [**Figure 10-12**]

MAGNETIZATION BY COOLING

This method can create a magnetized bar without any apparent magnet being present (just the Earth's field). The bar is heated to above its curie point which varies from metals but is typically hotter than red hot. At this point the bar has changed from being ferromagnetic to paramagnetic. As the bar cools it becomes ferromagnetic again and the field align with the external field. Demagnetization can be achieved by allowing the bar to cool in an East-West orientation shielded from magnetic influences.

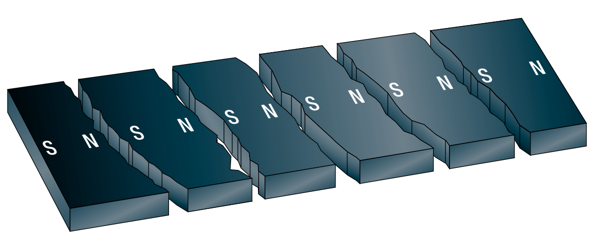


Figure 10-9. Magnetic poles in a broken magnet.

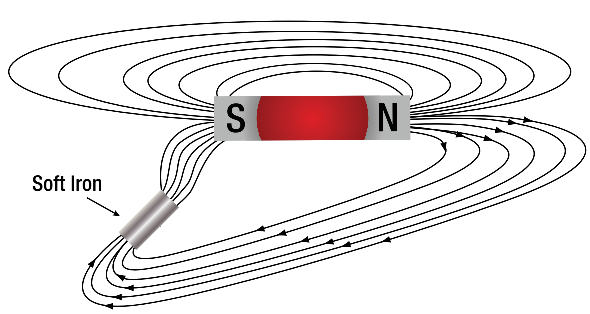


Figure 10-10. Effect of a magnetic substance in a magnetic field.

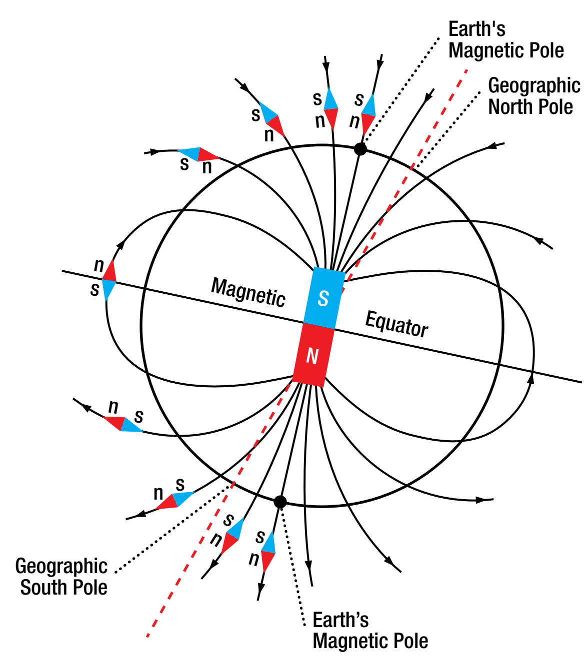


Figure 10-11. Earth's magnet.

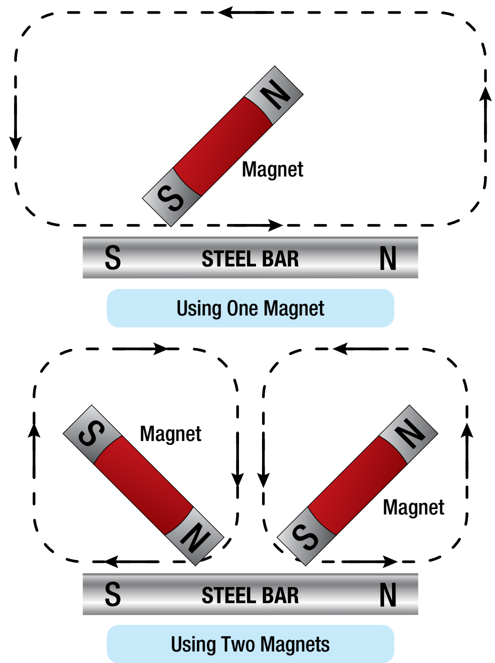


Figure 10-12. Magnetization with the stroking method.

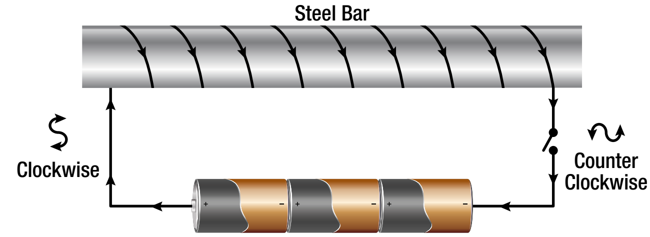


Figure 10-13. Magnetization by electricity.

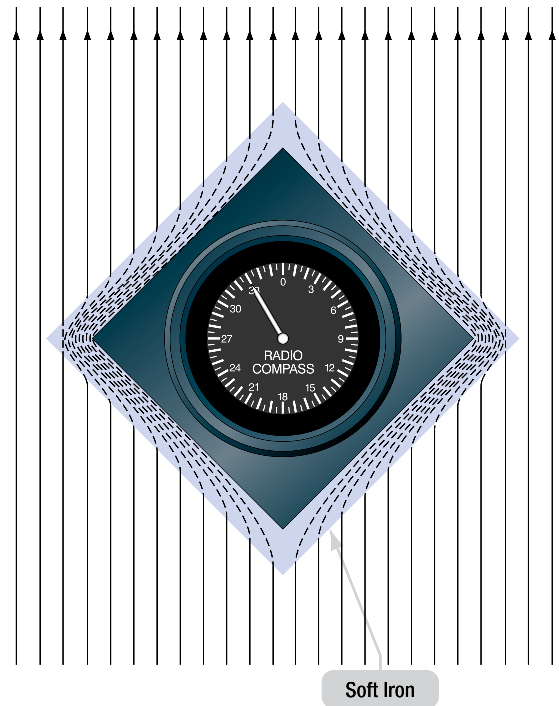


Figure 10-14. Magnetic shield.

MAGNETIZATION WITH ELECTRICITY
Modern methods tend to use electricity as it is easily controlled. A current passing through a coil will produce a magnetic field. The strength of the field is proportional to the current.

The polarity of the field is set by the path of conventional current in the coil. If at the end of the coil the current is flowing clockwise it will produce the south seeking pole. The other end will then be counterclockwise producing a north seeking pole. A higher current for a short duration is most efficient. [**Figure 10-13**]

Demagnetizing involves taking the bar through decreasing hysteresis cycles. An alternating current is used to create a field that overcomes the existing field in a magnet. Alternatively the rod can be drawn out and away from a constant amplitude alternating field.

MAGNETIC SHIELDING
There is no known insulator for magnetic flux, or lines of force, since they will pass through all materials. However, they will pass through some materials more easily than others.

Thus it is possible to shield items such as instruments from the effects of the flux by surrounding them with a material that offers an easier path for the lines of force. **Figure 10-14** shows an instrument surrounded by a path of soft iron, which offers very little opposition to magnetic flux. The lines of force take the easier path, the path of greater permeability, and are guided away from the instrument.

Materials such as soft iron and other ferrous metals are said to have a high permeability, the measure of the ease with which magnetic flux can penetrate a material. The permeability scale is based on a perfect vacuum with a rating of one. Air and other nonmagnetic materials are so close to this that they are also considered to have a rating of one. The nonferrous metals with a permeability greater than one, such as nickel and cobalt, are called paramagnetic. The term ferromagnetic is applied to iron and its alloys, which have by far the greatest permeability. Any substance, such as bismuth, having a permeability of less than one, is considered diamagnetic.

TYPES OF MAGNETIC MATERIAL
Magnets are either natural or artificial. Since naturally occurring magnets or lodestones have no practical use, all magnets considered in this study are artificial or man made. Artificial magnets can be further classified as permanent magnets, which retain their magnetism long after the magnetizing force has been removed, and temporary magnets, which quickly lose most of their magnetism when the external magnetizing force is removed.

Modern permanent magnets are made of special alloys that have been found through research to create increasingly better magnets. The most common categories of magnet materials are made out of Aluminum-Nickel-Cobalt (Alnicos), Strontium-Iron (Ferrites, also known as Ceramics), Neodymium-Iron-Boron (Neomagnets), and Samarium-Cobalt. Alnico, an alloy of iron, aluminum, nickel and cobalt, and is considered one of the very best. Others with excellent magnetic qualities are alloys such as Remalloy™ and Permendur™.

The ability of a magnet to hold its magnetism varies greatly with the type of metal and is known as retentivity. Magnets made of soft iron are very easily magnetized but quickly lose most of their magnetism when the external magnetizing force is removed. The small amount of magnetism remaining, called residual magnetism, is of great importance in such electrical applications as generator operation.

Horseshoe magnets are commonly manufactured in two forms. [**Figure 10-15**] The most common type is made from a long bar curved into a horseshoe shape, while a variation of this type consists of two bars connected by a third bar, or yoke.

Magnets can be made in many different shapes, such as balls, cylinders, or disks. One special type of magnet is the ring magnet, or Gramme ring, often used in instruments. This is a closed loop magnet, similar to the type used in transformer cores, and is the only type that has no poles.

Sometimes special applications require that the field of force lie through the thickness rather than the length of a piece of metal. Such magnets are called flat magnets and are used as pole pieces in generators and motors.

ELECTROMAGNETIC CONSTRUCTION AND PRINCIPLES

In 1820, the Danish physicist, Hans Christian Oersted, discovered that the needle of a compass brought near a current carrying conductor would be deflected. When the current flow stopped, the compass needle returned to its original position. This important discovery demonstrated a relationship between electricity and magnetism that led to the electromagnet and to many of the inventions on which modern industry is based.

Oersted discovered that the magnetic field had no connection with the conductor in which the electrons were flowing, because the conductor was made of nonmagnetic copper. The electrons moving through the wire created the magnetic field around the conductor. Since a magnetic field accompanies a charged particle, the greater the current flow, and the greater the magnetic field. **Figure 10-16** illustrates the magnetic field around a current carrying wire. A series of concentric circles around the conductor represent the field, which if all the lines were shown would appear more as a continuous cylinder of such circles around the conductor.

As long as current flows in the conductor, the lines of force remain around it. [**Figure 10-17**] If a small current flows through the conductor, there will be a line of force extending out to circle A. If the current flow is increased, the line of force will increase in size to circle B, and a further increase in current will expand it to circle C. As the original line (circle) of force expands from circle A to B, a new line of force will appear at circle A. As the current flow increases, the number of circles of force increases, expanding the outer circles farther from the surface of the current carrying conductor.

If the current flow is a steady nonvarying direct current, the magnetic field remains stationary. When the current stops, the magnetic field collapses and the magnetism around the conductor disappears.

The strength of the magnetic field of the electromagnet can be increased by either increasing the flow of current or the number of loops in the wire. Doubling the current flow approximately doubles the strength of the field, and in a similar manner, doubling the number of loops approximately doubles magnetic field strength. Finally, the type metal in the core is a factor in the field strength of the electromagnet.

A soft iron bar is attracted to either pole of a permanent magnet and, likewise, is attracted by a current carrying coil. The lines of force extend through the soft iron, magnetizing it by induction and pulling the iron bar toward the coil. If the bar is free to move, it will be drawn into the coil to a position near the center where the field is strongest. [**Figure 10-18**]

Electromagnets are commonly used in electrical instruments, motors, generators, relays, and other devices. Some electromagnetic devices operate on the principle that an iron core held away from the center of a coil will be rapidly pulled into a center position

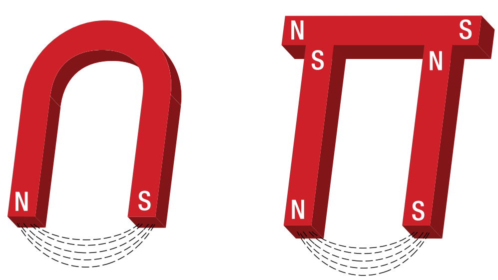


Figure 10-15. Two forms of horseshoe magnets.

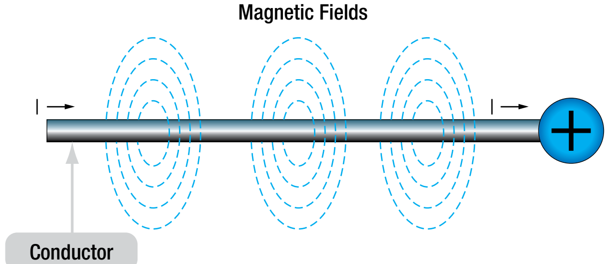


Figure 10-16. Magnetic field formed around a conductor in which current is flowing.

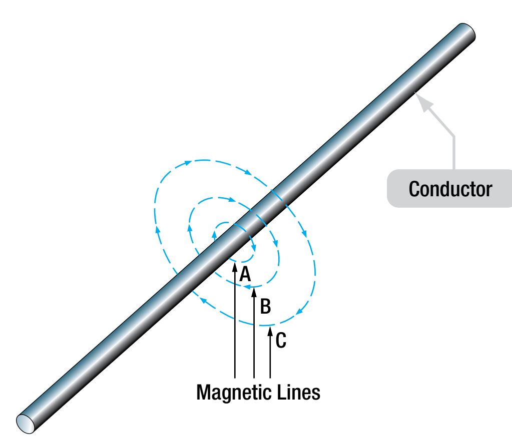


Figure 10-17. Expansion of magnetic field as current increases.