

SECTION 6, CHAPTER 2

MAGNETISM

List of Contents

	Para.		Para.
Introduction	1	Magnetic Effect of a Current ..	8
Laws of Magnetism	4	Current-Carrying Conductors in Mag-	
The Magnetic Field	5	netic Fields	11
Lines of Force	6	Residual Magnetism and Retentivity ..	14

List of Illustrations

	Fig.		Fig.
Magnetic Field of Two Bar Magnets		Polarity of Solenoid	4
with Like Poles Adjacent	1	Conductor in a Magnetic Field ..	5
Corkscrew Rule	2	Fleming's Left Hand Rule	6
Resultant Field of Two Conductors ..	3		

Introduction

1. Pieces of a certain form of iron ore, called lodestone or magnetite, have long been known to exercise on each other forces of attraction and repulsion when brought into reasonably close proximity. Such pieces of crude ore are termed **natural permanent magnets**, since they are found in the natural state and appear to retain their magnetic properties indefinitely. The magnetism, i.e. the property that is the source of the forces of attraction and repulsion displayed between two pieces of the ore, is most in evidence towards the ends of each piece, and these areas of apparent concentration of magnetic influence are known as the **poles** of the magnet.

2. A piece of natural magnetic ore when freely suspended will align itself in a definite direction relative to the position of certain areas of the earth which, from their apparent magnetic properties are known as 'magnetic poles'—these areas are located somewhere in the vicinity of the North and South geographic poles. The end of a natural magnet which points towards the 'North magnetic pole' is sometimes referred to as the 'north-seeking pole' of the magnet, but the term is generally abbreviated to **North** or **N pole**—the other end is naturally known as the **South** or **S pole**.

3. In addition to this direction-indicating property, a natural magnet can also impart its magnetic qualities to other pieces of iron

or ferrous materials which are not, of themselves, natural magnets—the ability of such materials to accept and retain this 'induced' magnetism depends largely upon the facility with which the atomic structure of the material can be influenced by magnetic forces, and it is generally found that a ferrous material which accepts induced magnetism readily shows very little ability to retain it, i.e. it is a temporary magnet.

Laws of Magnetism

4. The forces of magnetic attraction and repulsion can be studied by suspending two magnets and bringing them close together. It will be found that:—

- Like poles repel, unlike poles attract.*
- The force exerted between poles, whether of attraction or repulsion, is inversely proportional to the *square* of the distance between them.
- The two poles of a magnet have the same strength.

The Magnetic Field

5. The space surrounding a magnet in which the forces of attraction and repulsion are discernible is known as the **magnetic field** of the magnet. Strictly speaking the magnetic field is of infinite extent, but in practice the magnetic influence diminishes so rapidly with increasing distance that at a relatively small distance it ceases to be discernible—for practical purposes the field

(A.L. 12, Oct. 62)

of a magnet is only considered to extend to points where magnetic forces are still measurable.

Lines of Force

6. The field of a magnet can be shown (in one plane only) by drawing in, as lines, the paths which would be followed by 'isolated' magnetic poles free to move in the magnetic field—the 'isolated' magnetic pole is a purely theoretical concept, since in practice any magnetized body must possess N and S poles, but such a concept is most convenient in the study of magnetism. Lines of this nature are termed **lines of magnetic force** or **lines of magnetic induction**, and they are by convention based on the paths associated with N poles in movement, i.e. the arrowhead indications on the lines (Fig. 1) show the

to pass externally to the S pole, and thence through the magnet from S pole to N pole.

Magnetic Effect of a Current

8. When an electric current flows in a conductor a magnetic field is set up around the conductor. The lines of force which depict such a field take the form of concentric circles disposed around the surface of the conductor, both inside and out, and they are most closely concentrated at the actual surface of the conductor, indicating that magnetic effects are most pronounced in that region and that the magnetic field is strongest actually at the conductor surface—the strength of the magnetic field varies inversely with the square of the distance from the conductor surface, *not* from the centre of the conductor. The relationship between

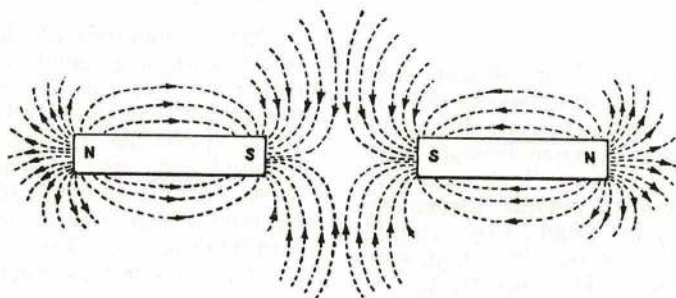


Fig. 1. MAGNETIC FIELD OF TWO BAR MAGNETS WITH LIKE POLES ADJACENT.

direction in which N poles would tend to move along the lines. From this it follows that lines of magnetic force are invariably shown as being directed *away from N poles* of a magnet system and *towards S poles*.

7. Lines of magnetic force are assumed to have the following properties:—

- (a) They are of an elastic nature, tending to contract along their length.
- (b) They never cross, and they tend to deflect, and be deflected by, other lines of force.
- (c) They concentrate through ferrous materials placed in the magnetic field which they represent; in doing so they induce magnetic properties into the material.
- (d) Each line forms an unbroken loop, leaving the magnet of origin by the N pole

the direction of current through the conductor and the direction of the magnetic field produced around the conductor is the same as that of the forward movement and rotation, respectively, of a screw with a right-hand thread or the familiar corkscrew (Fig. 2).

9. When two conductors which are carrying current lie parallel with each other, the magnetic field set up by each conductor will be affected by the field of the other, since the individual lines of force, although flexible, show a strong tendency to maintain their shape as concentric circles round their particular conductor. The resultant magnetic fields of two conductors are as shown in Fig. 3; it will be seen that where current flows in the same direction in both conductors the lines of force tend to encircle both conductors and so produce mutual attraction,

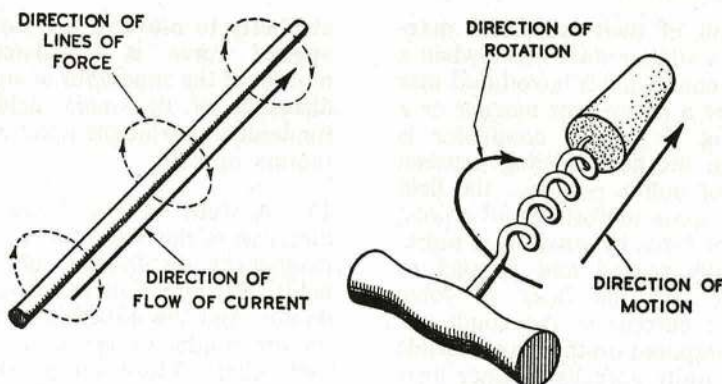


Fig. 2. CORKSCREW RULE.

while they are mutually repelled when current flows in opposite directions.

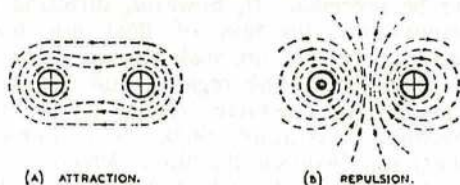


Fig. 3. RESULTANT FIELD OF TWO CONDUCTORS

10. If a conductor carrying current is formed into a single loop, the lines of force encircling the conductor will all pass through the loop in the same direction. A coil or solenoid is simply a conductor formed into a number of loops, and can be regarded as a number of conductors laid side by side. If a current is passing through the coil its direction is the same through each loop;

hence the magnetic field established by the current takes the form of lines of force which traverse the coil lengthwise and complete themselves through the surrounding medium. The form of the field of a current-carrying solenoid is thus similar to that of a simple bar magnet. The polarity of a solenoid, when carrying current, is easily ascertained by applying the *Right Hand Grasp Rule*; imagine the solenoid grasped by the right hand with the fingers pointing in the direction of the current (Fig. 4), then the outstretched thumb will point towards the N pole of the solenoid field. A reversal of current will, of course, produce a reversal of polarity, and the magnetic field will cease to exist when the current is discontinued.

Current-Carrying Conductors in Magnetic Fields

11. Forces of attraction or repulsion exist between conductors carrying current because

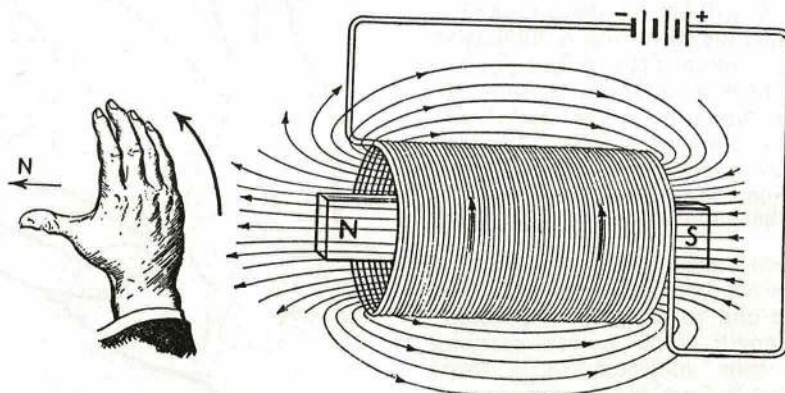


Fig. 4. POLARITY OF A SOLENOID.

of the interaction of their respective magnetic fields, and a similar state exists when a current-carrying conductor is introduced into the field of either a permanent magnet or a solenoid. In Fig. 5 such a conductor is shown located in the field existing between two pole faces of unlike polarity—the field is assumed to be quite uniform at all points, hence the lines of force by which it is represented are equally spaced and parallel to each other. At (A) the lines of force derived from the current in the conductor are shown superimposed on the magnet field: this is of course quite unrealistic, since lines of force never intersect, and the resultant

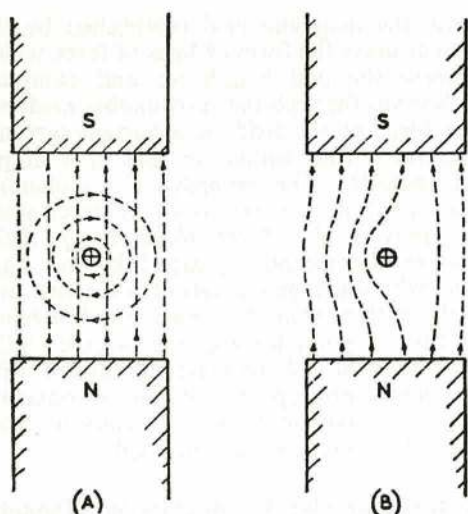


Fig. 5. CONDUCTOR IN A MAGNETIC FIELD.

field, consisting basically of the main (magnet) field distorted by the conductor field, is shown at (B). It will be seen that, on the left of the conductor, the distortion is such as to strengthen the resultant field at that point—the two sets of lines, as will be seen from (A), have the same direction at that point and thus produce a cumulative effect—while to the right of the conductor the two sets of lines are in opposition and so produce a weakening at that point of the resultant field.

12. It has been stated earlier that lines of magnetic force are considered to be elastic in their nature and to contract, if possible, along their length. The current-carrying conductor is thus subjected to a force tending to thrust it from the stronger region of the main field towards the weaker region, i.e. from left to right, and if the conductor is

at liberty to move in this direction then the applied force is translated into actual motion of the conductor at right angles to the direction of the main field. This is the fundamental principle upon which all electric motors operate.

13. A study of Fig. 5 will show that the direction of the lines of force due to the main magnet (i.e. the direction of the main magnet field), the direction of current in the conductor, and the direction of the force acting on the conductor are all at right angles to each other. Moreover, if either the direction of current in the conductor or the direction of the magnet field is reversed, then the strong and weak regions on opposite sides of the conductor are transposed: as a result of this the force acting on the conductor will also be reversed. If, however, direction of current and direction of field are both reversed, there is no such transposition of the strong and weak regions, and the force acting on the conductor retains its original direction. Obviously there is a definite connection between the three directions of current, field and applied force, and this relationship is given expression in *Fleming's Left Hand Rule*. To apply this very convenient rule, set the thumb, forefinger and middle finger of the left hand at right angles to each other as shown in Fig. 6: if the forefinger is aligned with the direction of the

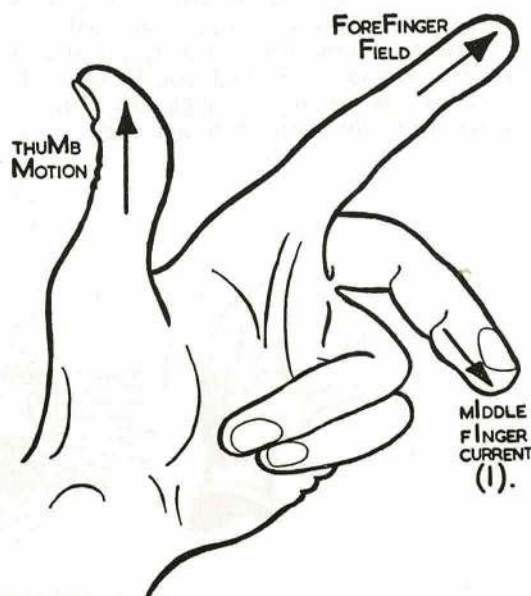


Fig. 6. FLEMING'S LEFT HAND RULE.

magnetic field and the middle finger with the direction of current in the conductor, then the thumb points in the direction in which the conductor tends to move. The rule can, of course, be applied to find any one of the three directions if the other two are known.

Residual Magnetism and Retentivity

14. When the current in a solenoid ceases to flow the magnet effect of the solenoid ceases to exist. If a core of iron or steel is fitted to the solenoid it will be found that the magnetization of the core, induced while current was flowing in the solenoid, will decrease to an extent which is closely related to the molecular rigidity of the metal. Thus steel, which is more difficult to magnetize than soft iron, will retain a much greater proportion of the magnetism. This property of retaining magnetism after removal of the magnetizing force is called **retentivity** or "remanence".

15. The magnetism which remains in iron or steel after the removal of the magnetizing

force is known as **residual magnetism**. This term should not be confused with "permanent" magnetism; observation will show that residual magnetism tends to disappear with the passage of time. In the case of soft iron the amount of residual magnetism is low and vanishes almost completely in a short time, while steel, being highly retentive, not only keeps a large amount of residual magnetism after the magnetizing force is removed, but tends to keep the major part of the magnetism almost indefinitely.

16. From the magnetic standpoint all substances can be classified under one of three headings. Iron, steel and nickel all show magnetic qualities when subjected to a magnetizing force, and are said to be "ferro-magnetic". Others, including most metals, show magnetic qualities to a very slight degree and are called "para-magnetic". The third group acts in the opposite way, tending to diminish the strength of a magnetic field when placed in it, and these materials are said to be "dia-magnetic".



This file was downloaded
from the RTFM Library.

Link: www.scottbouch.com/rtfm

Please see site for usage terms,
and more aircraft documents.