

# Domain Theory of Magnetism

The atoms of ferromagnetic substances may be thought of as tiny magnets with an N-pole and an S-pole. These atomic magnets, or dipoles, interact with their nearest neighbouring dipoles and a group of them line up with their magnetic axes in the same direction to form a magnetic domain. In an unmagnetized piece of iron there are millions of these domains, but they are pointing in random directions so that the piece of iron, as a whole, is not magnetized. The top diagram represents this unmagnetized condition.

When such a piece of iron is placed in a magnetic field (that is, near another magnet), the dipoles act like small compasses and rotate until they are aligned with the field. The piece of iron will then consist of a large number of dipoles pointing north and one end will become an N-pole, while the other end will become an S-pole. The next diagram shows the same piece of iron in the magnetized condition.

## Effects of the Domain Theory

### (a) Magnetic Induction

A permanent magnet brought near an iron nail will cause the iron nail to temporarily become a magnet. The field of the permanent magnet causes the dipoles in the iron nail to align, momentarily. If a steel needle is stroked continuously in one direction with a permanent magnet, its dipoles will align and, due to the carbon atoms in the steel, will stay aligned for some time, making the needle act like a permanent magnet.

### (b) Demagnetization

When a piece of iron becomes demagnetized, its aligned dipoles return to random directions. Dropping or heating an induced magnet will cause this to occur. Some materials, such as pure iron, revert to random alignment as soon as they are removed from the magnetizing field. Substances that become demagnetized spontaneously and instantly are called soft ferromagnetic materials. Iron may be alloyed with certain materials, such as aluminum and silicon that have the effect of keeping the dipoles aligned even when the magnetizing field is removed. These alloys are used to make permanent magnets and are referred to as hard ferromagnetic materials.

### (c) Reverse Magnetization

The bar magnets used in classrooms are made of hard ferromagnetic alloys, and they remain magnetized for a long time. The letter N is stamped on that end of the magnet to which all the N-poles of the aligned domains point. If a bar magnet is placed in a strong enough magnetic field of opposite polarity, its domains can turn and point in the opposite direction. In that case, the N-pole of the magnet is at the end marked S. The magnet is reverse-magnetized.

### (d) Breaking a Bar Magnet

Breaking a bar magnet produces two pieces of iron whose dipole alignment is identical to the original piece. Both pieces will also be magnets, with N-poles and S-poles at opposite ends. Continued breaking will produce the same results, since the domains within the magnet remain aligned even when the magnet is broken.

### (e) Magnetic Saturation

In most magnets, a large number of the dipoles are aligned in the same direction, but not all.

The strength of a bar magnet may be increased only up to a certain level. The peak will occur when as many as possible of its dipoles are aligned. The material is then said to have reached its magnetic saturation.

### (f) Induced Magnetism by the Earth

If a piece of iron is held in the Earth's magnetic field and its atoms are agitated, either by heating or by mechanical vibration (that is, by hitting the iron with a hammer), alignment of its dipoles will result. This is most easily accomplished by holding the piece of iron pointing north and at the local angle of inclination, while tapping it with a hammer.

Steel columns and beams used in building construction are invariably found to be magnetized. Steel hulls of ships and railroad tracks are also magnetized by the Earth's magnetic field.

### (g) Keepers for Bar Magnets

In time, a bar magnet will become demagnetized as the poles at its ends begin to reverse the polarity of the atomic dipoles inside it. If bar magnets are stored in pairs with their opposite poles adjacent and with small pieces of soft iron (called "keepers") across the ends, demagnetization does not occur. The keepers themselves become strong induced magnets and form closed loops of magnetic dipoles, thus preventing demagnetizing poles from forming.

## Summary & Review of Magnetism

1. Certain materials such as lodestone are capable of exerting magnetic forces and are called magnets. The forces are concentrated at opposite ends of a magnet, in areas called poles.
2. There are two characteristic poles of magnetic force, called north-seeking and south-seeking. The fundamental law of magnetic poles states:

**Similar Poles Repel**

**Opposite Poles Attract**

3. The region of magnetic force around a magnet is called a magnetic field and is represented by magnetic field lines that show the direction of the force on the N-pole of a small test compass at each point in the field.
4. The Earth has a magnetic field similar to that of a bar magnet, with its S-pole located near the geographic north pole of the Earth. Compasses point to this pole, called the magnetic north pole, and the angle between the magnetic north pole and the geographic north pole at any point on the Earth is called the magnetic declination.
5. The Earth's magnetic field has two components, the vertical and the horizontal, and the angle between the direction of the Earth's magnetic field (which varies) and a horizontal line pointing north is called the magnetic inclination, or dip.
6. Substances containing iron, nickel, or cobalt may be induced to become magnets by being placed in a magnetic field. They are called ferromagnetic materials.
7. Induced magnetism may be explained by means of the theory of domains. Ferromagnetic materials are composed of a large number of tiny magnetic dipoles. Groups of aligned dipoles form magnetic domains that are normally oriented at random. In the presence of a magnetic field, the dipoles turn so that most domains are aligned to form a magnet.
8. The **domain theory** may be used to explain:
  - (a) magnetic induction
  - (b) demagnetization of a temporary magnet
  - (c) reverse magnetization of a bar magnet
  - (d) the breaking of a bar magnet into a large number of smaller magnets
  - (e) magnetic saturation
  - (f) magnetism induced by the Earth
  - (g) keepers for bar magnets

### Review

1. What name is given to materials that are strongly attracted by a magnet? Name two such materials, other than iron and steel.
2. Describe how a screwdriver could be magnetized. What might happen if the screwdriver were heated or dropped? Explain your answer.
3. What name is given to the region in which a magnet influences other magnetic materials? How far does this region extend?
4. Describe two ways in which you could detect the presence of a magnetic field. Does any magnetic field exist in the spaces between the lines of iron filings around a magnet? Explain your answer.
5. Is the magnetic pole area in the northern hemisphere an N-pole or an S-pole? Explain.
6. Vertical retort-stand rods in laboratory classrooms are often found to be magnetized, and the polarity of such rods in Canada is opposite to the polarity of those in Australia. Explain this statement.
7. Given two apparently identical bars of steel, one a permanent magnet and the other unmagnetized, and without the help of any other equipment, describe a method for determining which bar is the magnet.
8. Describe what would happen to a magnetic compass and to a dipping needle if each were placed (a) at the magnetic north pole, and (b) at the equator.
9. Using the domain theory, explain the difference between soft iron and steel, and indicate which you would select for use as (a) a compass needle, and (b) keepers for a pair of bar magnets.