7.2 EXISTENCE OF MAGNETIC FIELD

The magnetic force between magnets act at a distance, i.e., the magnets exerting force on each other do not have to be in physical contact with each other. This is similar to the action-at-distance behavior of electric and gravitational forces. Imagining a field picture brings advantage of local description of a force. The magnetic force may be understood in terms of the magnetic field of a magnet as explained by Michael Faraday. The magnetic field will be denoted by $\vec{B}$. Magnetic field is a vector field similar to electric field since it is given by vector values at space points. You can visualize the magnetic field of a magnet by sprinkling iron filings near the magnet as shown in Fig. 7.9. The iron particle get magnetized in a magnetic field and stick together along magnetic field lines as seen in the picture.

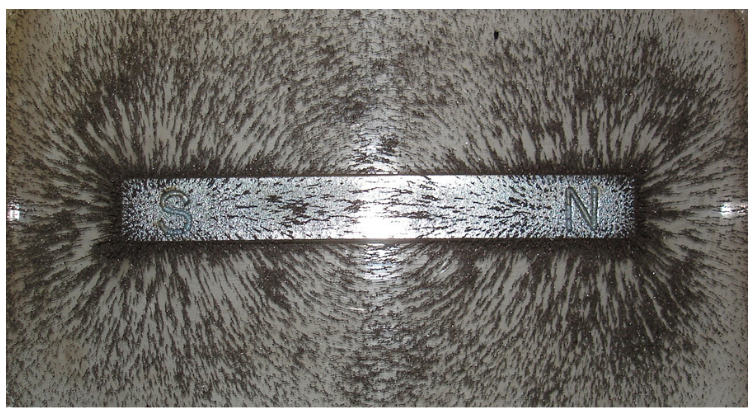

Figure 7.9: Magnetic field lines visualized by sprinkling iron particles near a magnet.

As indicated in our discussion above that North Pole of a magnetic needle or a compass points towards South Pole of a magnet. Therefore, the direction of North Pole of a magnetic needle serves to indicate the direction of magnetic field at the point. The strength of magnetic field requires a measurement of torque on a test magnetic needle or a magnetic force on moving charge as we will see below.

The magnetic field inside the magnetic body continues from South Pole to the North Pole. Since, there are no magnetic charges in a magnet, the magnetic lines do not terminate. Instead, magnetic lines form loops as shown schematically for a bar magnet in Fig. 7.10.

Therefore, outside a magnet the magnetic field lines come out of the north pole and land on the south pole, and inside the magnet, the magnetic field lines continue from South Pole to the North, where they meet the corresponding emerging lines. The magnetic field lines

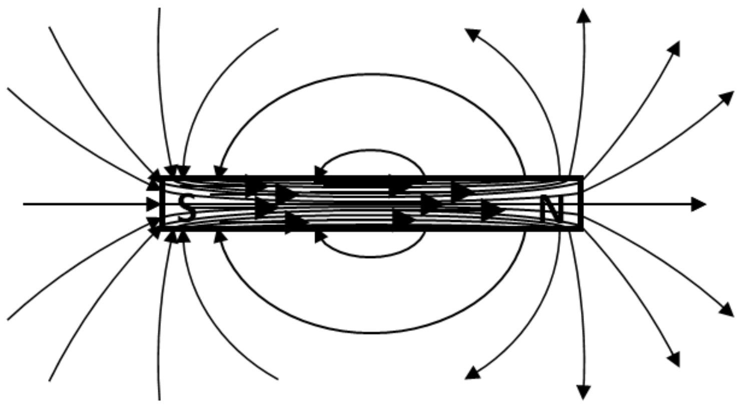

Figure 7.10: Magnetic field lines of a bar magnet.

make closed loops, which is one major difference with the electric field lines.

Similar to the electric field lines, when drawing magnetic field lines, we represent strength of the magnetic field in the region by drawing sufficient number of lines so that the "density of lines" corresponds to the strength of the magnetic field in the region. Thus, the density of lines is higher near the poles of the magnet than far away from the poles, and it is highest inside the magnet since all lines must pass through the magnetic body.

When magnetic field lines are straight, then the direction of the lines are the direction in which a magnetic needle will point in the direction of South-to-North when placed at that point. If the lines are curved, then the tangent to magnetic field lines gives us the direction in which a tiny magnetic needle will point if placed there.

We have seen above that there is a magnetic force between a current carrying wire and a magnet. Actually, you can demonstrate a magnetic force between two current carrying wires as we will see below. The magnetic force on a magnet by a current carrying wire is indistinguishable from the magnetic force of another magnet. Therefore, to understand the magnetic force of a current carrying wire, we say that electric current has magnetic field just like the magnetic field of other magnets.

The effect of current in a straight wire was shown to align magnetic needles such that they pointed along circles. This says that the magnetic field lines of a straight wire with a current are circles around as shown in Fig. 7.7.

The magnetic field of coils of wire carrying current is more like the magnetic field of a bar-magnet as shown in Fig. 7.11. The magnetic

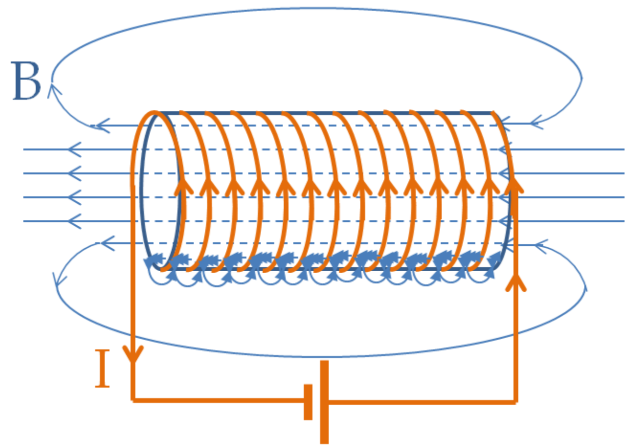

Figure 7.11: Magnetic field lines of current through coils of wire. You can compare the magnetic field lines here to that of a bar magnet. In the present configuration, the analogy shows that right side of the coil acts as "South Pole" and the left side as "North Pole".

field of current through coils is straight near the middle of the loops. If the coils are tightly wound, then the magnetic field on the sides are nearly zero and one obtains uniform magnetic field inside the space enclosed by the coils. You can try to see how these magnetic field lines help explain the attraction and repulsion of magnet shown in Fig. 7.8.