Why is electric current induced when the magnet and the electric circuit approach each other or move farther away from each other? There is a good way to understand this from the point of view of magnetic force. Suppose, the magnet is at rest, and an electric circuit is approaching it. See Fig. 1. Now, remember that there are a lot of positive charges and negative charges in the electric circuit, even though their net charge is zero, which makes the electric circuit neutral. Given this, let's figure out what direction of magnetic forces each positive charge and negative charge receives. First, the positive charge. See Fig.2. Fig 2.(a) is a perspective view, Fig. 2.(b) is the side view and Fig. 2. (c) is the downward view. As the electric circuit is moving upward, the positive charge is moving upward as well, which makes the electric current due to the positive charge in upward direction. If you remember our earlier article "Magnet exerts force on wire through which electric current passes," you will see that the positive charge will receive a force to move around counterclockwise direction inside the circuit. This will make the positive charge receive a force rotating counterclockwise direction. Now, the negative charge. See Fig.3. We have drawn only the downward view. As the electric circuit is moving upward, the negative charge is moving upward as well, which makes the electric current due to it in downward direction. Therefore, it receives a force in clockwise direction.

In conclusion, the positive charges receive a force to rotate around anticlockwise direction, while the negative charges receive one to rotate around clockwise direction. This implies that electric field rotating anticlockwise direction is induced, and the electric current rotating anticlockwise direction is induced.

Therefore, we successfully explained Faraday's law of induction from the point of view of magnetic force on the electric charges inside the electric circuit. However, this view seems to fail in case the magnet is moving instead of electric circuit. Nevertheless, according to the old Galilean principle, we never know which one is moving. All motions are relative. Even if you are at rest, from the point of view of your friend who are on a train, you are the one moving. If the train is moving at a constant velocity, the law of physics is equally well applied inside it. If you drop an eraser, you will see that it drops right below, not backwards. (Remember the discussion in our earlier article "Newton's first law.') Therefore, even when the magnet is the one moving, not the electric circuit, the electric current must be induced.

This observation was very important in formulating Einstein's special relativity. In his seminal paper on special relativity, Einstein wrote:

"Take, for example, the reciprocal electrodynamic action of a magnet and a conductor

The observable phenomenon here depends only on the relative motion of the conductor and the magnet, whereas the customary view draws a sharp distinction between the two cases in which either the one or the other of these bodies is in motion….

Examples of this sort, together with unsuccessful attempts to discover any motion of the earth relative to the "light medium," suggest that the phenomena of electrodynamics as well as of mechanics possess no properties corresponding to the idea of absolute rest."

I am sure that you understand what Einstein meant, if you read our earlier articles "Newton's first law," and "Why is the speed of light constant?" We will re-visit the content treated in this article quantitatively in our article "Faraday's law of induction and the Lorentz force."

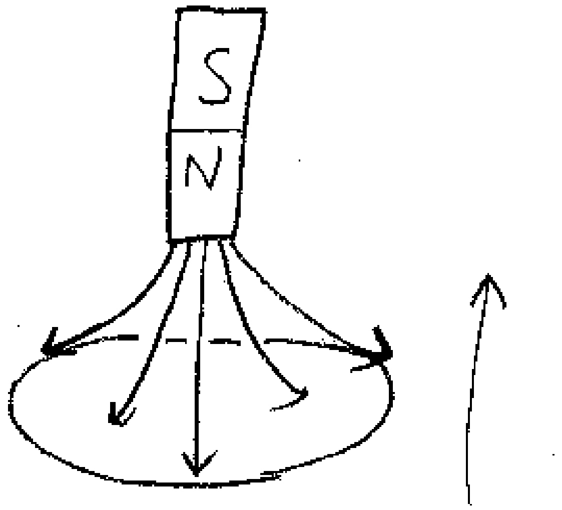
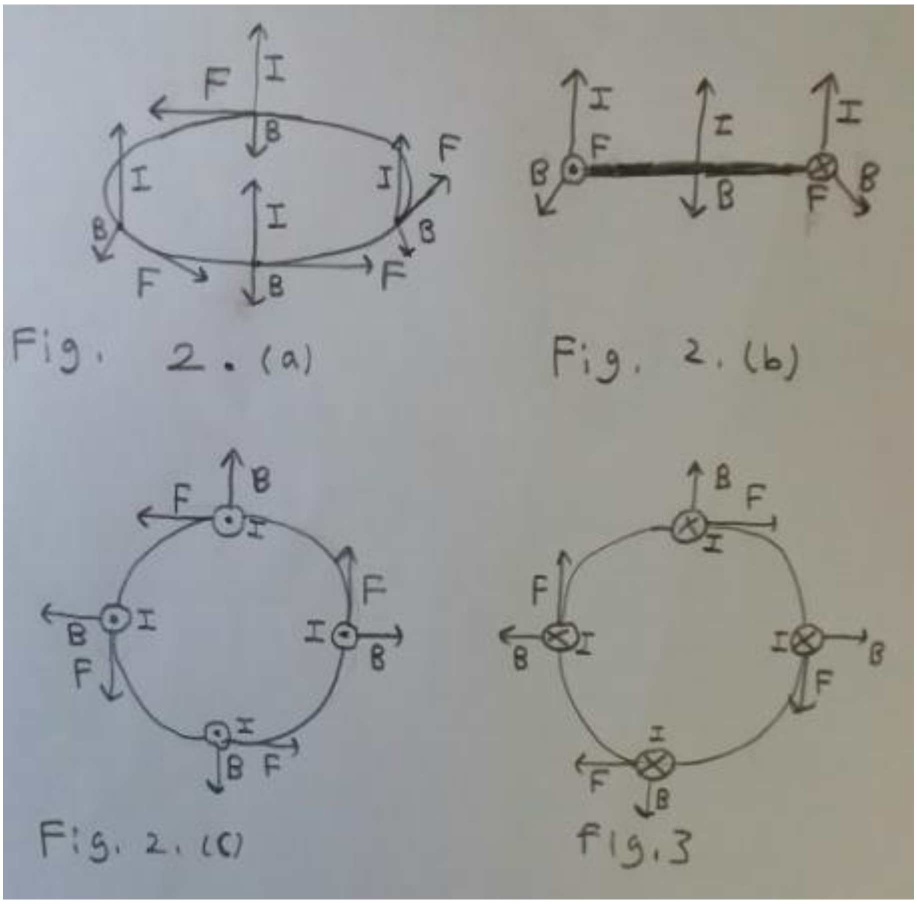


Fig 1



Let me conclude this article with a comment. See Fig. 4. Suppose we now have four positive electric charges instead of an electric circuit, and we approach a magnet toward the charges. In this article, we have seen that the positive charges will receive forces as in Fig. 2(c). It means that they are receiving the torque rotating in counterclockwise direction. So, they gain some angular momentum. However, this seems troublesome because there was initially no angular momentum, and angular momentum is always conserved! In our later article "Poynting vector," we will see how this paradox is resolved. I would have liked to explain the resolution right away, but you need to learn more math to understand Poynting vector.

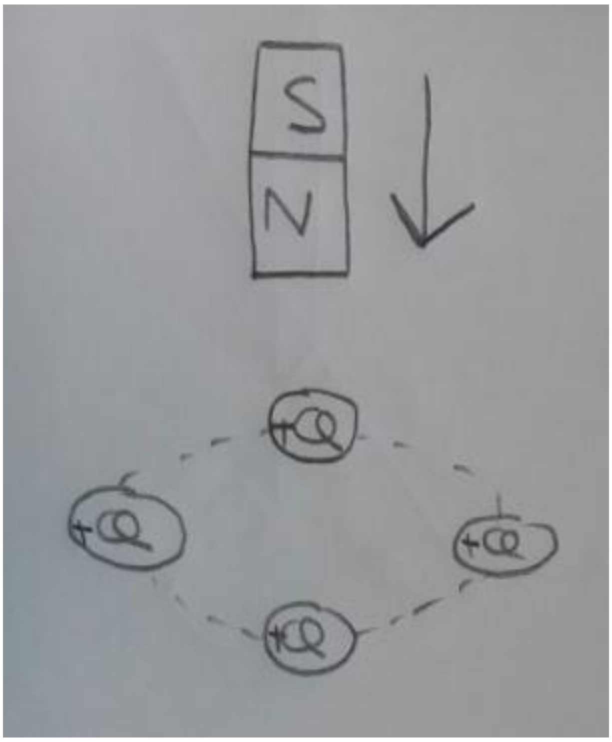


Fig 4

Summary

Faraday's law of induction can be understood from the point of view of magnetic force combined with Galilean principle.