Introduction

Where do we encounter Electricity and Magnetism?
In the mechanized world it is found in every gadget we use. It is not only the power which drives the gadgets but the particular function of the devices are based on electricity and magnetism. The lights, the fans, the heater, watches, the door bell, the microwave oven, the communication and audio visual gadgets and so on. It is rare to find a device that doesn't work on electricity and magnetism. It must be mentioned that a number of devices work on the principles of thermodynamics and aerodynamics which are essentially large scale collective phenomenon. These are the automobile engine, the air conditioners, the refrigerators, the aircrafts etc.

It may seem that this is because we understand the phenomenon of electricity and magnetism very well and for quite long. But the real reason is that almost every natural phenomenon that we experience, that we can touch and feel, ordinarily, are electromagnetic in nature. The earth on which we stand, the chair on which we sit is possible because of an enormous electrostatic repulsion between the electrons of two surfaces in contact. If this was not so we would have fallen through the floor or walked through a wall like two clouds passing through each other. We call this force that prevents us from falling through as the normal force. Friction is also due to adhesive force between the surfaces in contact which is due to the electrostatic forces between the atoms. The strength of a string or the elasticity of a material is due to electrostatic forces between the molecules of the material. All the biological phenomenon are electrostatic. The messages carried by the nerve cells are electric pulses. The movement of the muscles through contraction and relaxation is through electric impulses. Our vision, our taste and touch are basically electrostatic in nature.

If we notice carefully, our present understanding of physics implies that it ought to be so. There are four fundamental forces of nature, the electromagnetic , the gravitational, the strong nuclear force and the weak nuclear force. Out of these the strong and the weak forces are subatomic. Their range is about 10^{-14}m. This is the range which we can't perceive naturally. The laws of classical physics don't hold at such scales. They are governed by the laws of quantum mechanics, which we cannot comprehend at the large scales that we can ordinarily observe and measure. The electromagnetic and the gravitational forces operate at ordinary and large scales. So every physical phenomenon that we perceive ordinarily like the motions of the planets, moon and stars or the commonplace phenomenon on earth are either gravitational or electromagnetic. Out of these the gravitational forces are too weak at ordinary sizes that we work with. They are important only at a very large scale like the size of the earth while they can safely be ignored when we analyze the motion of billiard balls or surfaces in contact. So the only force that drives our naturaland mechanized world is electromagnetic.

With ever increasing advancement in communication the electromagnetic phenomenon have gained a lot of importance. The communication is through electromagnetic waves in space or electromagnetic signals through cables. The role of antenna design for transmission and receivers is gaining enormous importance. The devices are getting miniaturized and so are the needs of the antennas to be miniaturized. These devices are no more stationary but mobile. An engineer working in the field of communication has to understand the basics of electromagnetic theory to keep up with the changing technology.

In the late eighteenth century the theory of electrostatics developed due to extensive work by Benjamin Franklin and Charles-Augustin de Coulomb. Quantitative theory of electricity was established by Coulomb's law. The theory needed the idea of force exerted by one charge on another at a distance r. This was one of the instances where a force between two bodies can be exerted without them being in contact. The successful theory of gravitation by Newton had already proposed it but this was the first time action at a distance was employed at ordinary distances. In all other ordinary experiences force could be exerted only through physical contact between two bodies. Magnetism was independent of electricity. It dealt with natural magnets, iron pieces and the earth's magnetic forces. Ampere established the relation between electric current and magnetism. Magnetism was completely understood through current carrying conductors by Ampere's law. Here again the idea of an action at a distance was employed.

Though instantaneous action at a distance was not much of a concern in prerelativity era, the idea of force being transmitted through free space needed a physical understanding. The idea of a field was hypothesized to deal with such actions at a distance. Every charge is hypothesized to carry an electric field around it. Another charge at a distance feels the presence of this field and hence experiences a force. Similarly a current carrying wire or a magnet carries a magnetic field around it. Any other magnet feels the presence of this field and experiences a magnetic force.

In 1831 Faraday demonstrated that a changing magnetic field can generate an electric current in a conductor. This unified the two apparently different forces as one, called the electromagnetic force. Maxwell finally developed a complete unified theory of electromagnetism where the time and space variation of the two kinds of field are related to each other. Though the strength of these fields are related to the real sources,the charges and the currents, once these time varying fields are generated they can exist independent of their sources. This gives a real physical existence to these fields independent of the physical sources. So the fields are no more hypothetical quantities needed to just explain action at a distance. Maxwell's theory gives wave equation for time varying electromagnetic field. These waves propagates through space at the speed of light and hence light is understood to be an electromagnetic phenomenon. The concerned fields are vector functions of time and space. They are called vector fields. In order to understand this beautiful development of physics we have to equip ourselves sufficiently with vector calculus. Our understanding of the language of vector calculus will make the learning of electromagnetic theory a beautiful experience. So we start with vector calculus.