15.4: Forces on Currents in Conductors

So far we have talked mainly about point charges moving in free space. However, many practical applications of electromagnetism have charges moving through a *conductor* such as copper. A conductor is a material in which electrically charged particles can freely move. An *insulator* is a material in which charged particles are fixed in place. Practical conductors are often surrounded by insulators in order to confine the motion of charge to particular paths.

The *current* through a wire is defined as the amount of charge passing through the wire per unit time. When defining current, one needs to decide which direction constitutes a positive current for the problem at hand, i. e., the direction in which the positive charge is moving. If the current consists of particles carrying negative charge, then the direction of the current is opposite the direction of the motion of the particles.

Metals tend to be good conductors, while glass, plastic, and other non-metallic materials are usually insulators. All materials contain both positive and negative charges. In metals, negatively charged electrons can escape from atoms and are free to move about the material. When atoms lose one or more electrons, they become positively charged. Atoms tend to be fixed in place. Since the electron charge is negative, the current in a wire actually has a direction opposite the direction of motion of the electrons, as noted above.

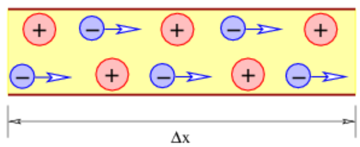

Figure 15.4.5:: Stationary positive charge and negative charge moving to the right with speed v in blown up segment of wire.

If a conductor is in the form of a wire, we can compute the magnetic force on the wire if we know the number of mobile particles per unit length of wire N, the charge on each particle q, and the speed v with which they are moving down the wire. The total force on a length of wire L is $\mathbf{F} = \mathrm{qNLVn} \times \mathbf{B}$, where $\boldsymbol{n}$ is a unit vector pointing in the direction of motion of the particles through the wire. The quantity $\mathrm{i} \equiv \mathrm{gNv}$ is called the current in the wire. It equals the amount of charge per unit time flowing down the wire. Written in terms of the current, the force on a length L of the wire is

$$\mathbf{F} = iL\mathbf{n} \times \mathbf{B} \tag{15.4.1}$$