10.1 FARADAY'S DISCOVERIES

In April of 1820 Hans Christian Øersted in Denmark discovered that magnetic needles respond to electric currents. In the same year Marie Ampere in France found that magnets exert force on current-carrying wires. Ampere also demonstrated that wires carrying currents exerted force on each other. These findings brought great excitement to the scientific community in 1820s since they provided definite experimental evidence of the close connections between electricity and magnetism - the two fields that had been hitherto separate and distinct from each other.

Soon people began to wonder if a magnetic field would produce an electric current as well and many ideas were tested. Most of these experiments didn't go anywhere. For instance, strong magnets next to a wire failed to produce any detectable current in the wire. Even the magnetic field produced by large steady currents in a wire failed to cause any current in a loop of wire next to the first wire. We call these experiments **null experiments** since the result is zero. They are illustrated in Fig. 10.1.

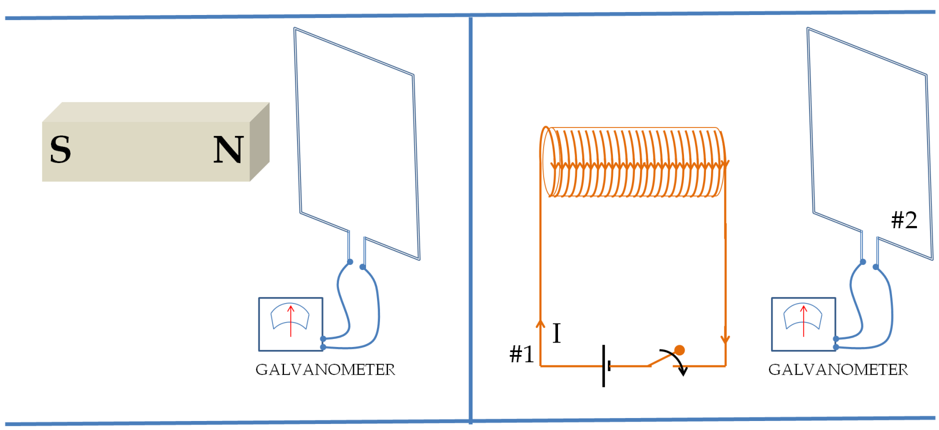

Figure 10.1: **The Null Experiments**. (a) When a loop of conducting wire and a magnet are fixed in their places no current is observed in the loop regardless of the strength of the magnet. (b) When a loop of conducing wire is near a current carrying wire, no current is observed in the loop if the current in the current-carrying wire is steady or if there is no relative motion between the two wires.

Around 1831 **Michael Faraday** found the missing link in these studies. He discovered that the electric effect of a magnetic field required that *something must be changing with time*. He observed that when the magnet is moving near a loop of wire a current is detected in the wire, but when the magnet stopped moving, there was no current in the wire as illustrated in Fig. 10.2.

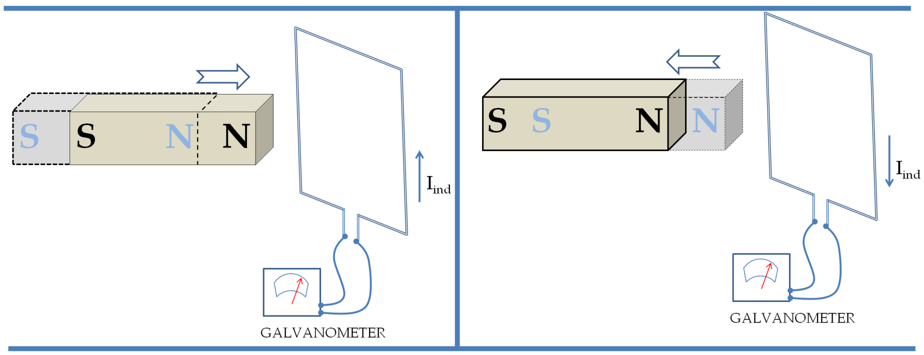

Figure 10.2: **Moving magnet causes an induced current**. (a) When a magnet is moving towards a loop of conducting wire an induced current appears in the loop of wire as detected by the galvanometer. (b) When the magnet is moving away induced current has the opposite direction. When there is no relative motion of the magnet and the loop no current is induced. Only during the time there is motion, there is induced current.

Similarly, if a loop of wire was moving in a space where there was a magnetic field, then a current was detected in the wire when the wire was moving but no current when the wire was not moving as illustrated in Fig. 10.3.

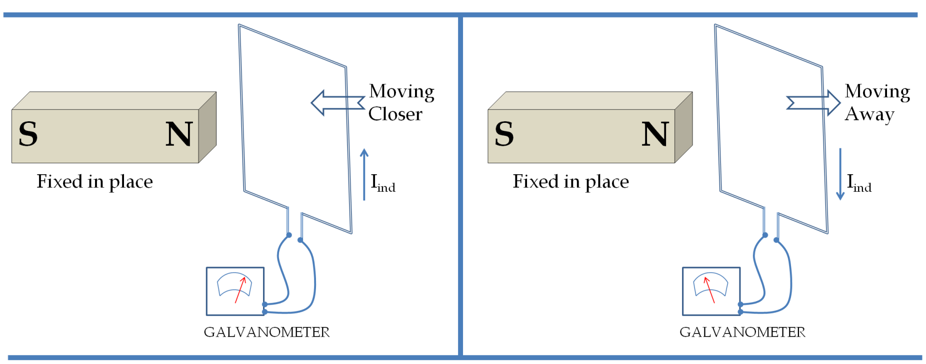

Figure 10.3: **Moving loop in a magnetic field induces a current**. (a) When a loop of wire of conducting wire is moving in a space where there is a magnetic field, the loop develops an induced current as detected by the galvanometer. (b) When the loop is moving in the opposite direction the induced current has the opposite direction. When there is no relative motion of the magnet and the loop no current is induced. Only during the time there is motion, there is induced current.

In a pair of wires when one wire has a changing current then simultaneously a current was detected in the other wire even though there was no apparent current source in the second wire, but when the current in the first wire was not changing, then there was no current in the second wire as illustrated in Fig. 10.4. In all these situations, we say that **currents are induced**.

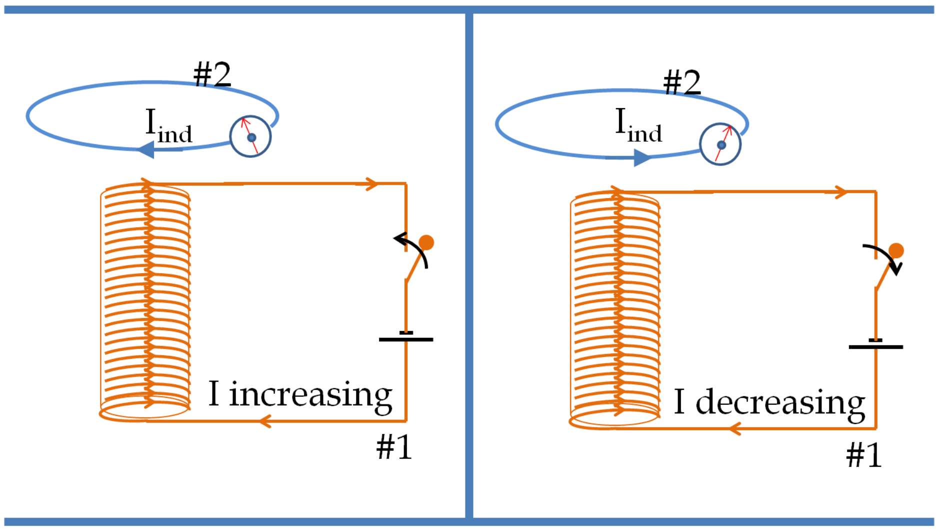

Figure 10.4: **Changing current in one loop creates an induced current in another loop**. During the time when the current in the loop # 1 is changing, an induced current is observed in the loop # 2. (a) When the switch in circuit #1 is closed, the current increases from zero to a non-zero value. During the time the current is increasing in loop # 1, the galvanometer shows that there is an induced current in loop # 2. (b) When the switch in circuit #1 is opened, the current drops from a non-zero value to zero. During the time the current is decreasing in loop # 1, the galvanometer shows that there is an induced current in loop # 2, which is in the opposite direction to the induced current when the current in # 1 was increasing. When the current is loop # 1 is steady, no induced current occurs in loop #2 regardless of the value of the current in loop # 1.