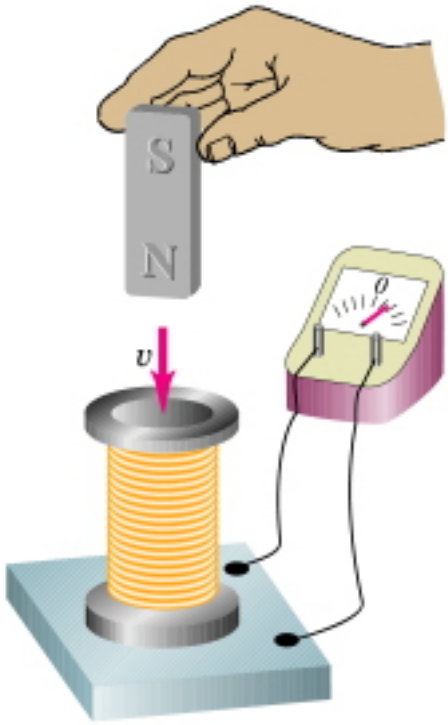
Electromagnetic Induction

The discovery that an electric current in a wire could produce a magnetic field was a turning point in physics, opening the door for a number of technological improvements that changed the world.

A natural question that arose from this discovery was whether magnetism could be used to produce an electric current in a wire. In 1831, Michael Faraday and Joseph Henry both independently discovered that the answer is yes.

Faraday and Henry both discovered that electric current could be produced in a wire by simply moving a magnet into or out of a coil of wire, as shown to the right.



No battery or other voltage source was needed—only the motion of the magnet in a coil or in a single wire loop.

Until the work of Faraday and Henry, the only device capable of producing an electric current was the voltaic cell, which only produced small currents. This was the forerunner of the modern battery.

The discovery made by Faraday and Henry provided a major alternative to the voltaic cell. Their discovery changed the world by making electricity so common that it would power industries by day and light up cities by night.

How to Induce a Current

Faraday and Henry discovered that a current was induced by the relative motion of a wire with respect to a magnetic field. When there is no relative motion, there is no current induced.

The current in the coil is called an **induced current** because it is brought about (induced) by a changing magnetic field. Since a voltage source is needed to produce a current, the coil of wire acts as if it were a voltage source. We call this an **induced voltage**.

Faraday and Henry also discovered that the direction of the motion of the magnet mattered. When the magnet moves away from the coil, a current is produced that moves in one direction around the coil. When the magnet moves towards the coil, a current is produced that moves in the opposite direction around the coil.

After many observations, Faraday and Henry concluded that the current induced in the coil resulted from the fact that the magnetic field inside the coil was changing when the magnet moved. Once they realized that a changing magnetic field was responsible for the induced current, Faraday and Henry were able to identify several other ways to generate an induced current:

1. Move the magnet towards (or away from) the coil.
    - as the magnet moves towards the coil, the magnetic field inside the coil gets stronger
    - as the magnet moves away from the coil, the magnetic field inside the coil gets weaker
2. Move the coil of wire towards (or away from) the magnet.
    - as the coil moves towards the magnet, the magnetic field inside the coil gets stronger
    - as the coil moves away from the magnet, the magnetic field inside the coil gets weaker
3. Change the strength of the magnetic field.
4. Rotate the coil of wire in a magnetic field.
5. Change the area of the coil of wire.

Factors that Affect Induced Voltage

Faraday investigated what factors influence the magnitude of the induced voltage. He discovered that the amount of voltage induced in a coil of wire depends on the following factors:

1. How quickly the magnetic field changes.
    - a very slow change results in a very small induced current
    - a quicker change results in a larger induced current
2. The area of the loop.
3. The orientation (angle) of the loop relative to the magnetic field lines.
4. The number of loops in the coil of wire.
    - the greater the number of loops, the greater the induced voltage

- pushing a magnet into twice as many loops will induce twice as much voltage, pushing it into ten times as many loops will induce ten times as much voltage, and so on

Factors that Affect Induced Current

The amount of current produced by electromagnetic induction depends on two things:

1. The magnitude of the induced voltage.

    - a large voltage will result in a larger current

2. The resistance of the coil of wire and the circuit to which it is connected.

    - a larger resistance will result in a smaller current