# 8.5.2: Electromotive Force

Hydroelectric power generator

Figure 19.2.1

Electrical generators convert mechanical energy into electrical energy. Every electrical generator needs some method for spinning the coil inside the magnetic field. Hydroelectric generators use water pressure to spin the coil while windmills, of course, use the wind to spin the coil. The image here is a combination of steam turbine and generator. The steam can be produced by burning coal or diesel fuel or by a nuclear reaction and the steam then turns the coil and generates electricity.

## Electromotive Force

When an individual charge flies through a magnetic field, a force is exerted on the charge and the path of the charge bends. In the case shown in the sketch below, the charge is positive and the right hand rule shows us the force will be upward, perpendicular to both the field and the path of the charge.

Charge passing through a magnetic field

Figure 19.2.2

If a wire that is part of a complete circuit is moved through a magnetic field, the force on the individual electrons in the wire occurs in exactly the same manner. Since the electrons in the wire are negatively charged, the force would be in the opposite direction but otherwise the situation is the same. When the wire is pulled downward through the magnetic field, the force on the electrons cause them to move within the wire. Since the charges are negative, the left hand rule shows that the electrons would move as diagrammed in the sketch. (Point fingers in the direction of the magnetic field, point thumb in the direction of wire movement, and palm shows direction of electron flow.) No current will flow, of course, unless the section of wire is part of a complete circuit.

Diagram of a conducting rod being passed through a magnetic field

Figure 19.2.3

This process allows us to convert mechanical energy (the motion of the wire) into electrical energy (the current). This is the opposite of what happens in an electric motor where electrical energy is converted into mechanical energy.

In order to maintain a constant current flow, it is necessary to have a potential difference or voltage in the circuit. The voltage or potential difference is also frequently referred to **electromotive force**. The term electromotive force, like many historical terms, is a misnomer. Electromotive force is NOT a force, it is a potential difference or potential energy per unit charge and is measured in volts. The potential difference in the case of moving a wire through a magnetic field is produced by the work done on the charges by whatever is pushing the wire through the field.

The EMF (or voltage) depends on the magnetic field strength, B, the length of the wire in the magnetic field, l, and the velocityof the wire in the field.

$$\text{EMF}=Blv$$

This calculation is based on the wire moving perpendicularly through the field. If the wire moves an angle to the field, then only the component of the wire perpendicular to the field will generate EMF.

**Example 19.2.1**

A 0.20 m piece of wire that is part of a complete circuit moves perpendicularly through a magnetic field whose magnetic induction is 0.0800 T. If the speed of the wire is 7.0 m/s, what EMF is **induced** in the wire?

**Solution**

$$\text{EMF}=Blv=(0.0800\ \text{N/A}\cdot\text{m})(0.20\ \text{m})(7.0\ \text{m/s})=0.11\ \text{N}\cdot\text{m/C}=0.11\ \text{J/C}=0.11\ \text{V}$$

## Summary

- If a wire that is part of a complete circuit is moved through a magnetic field, the magnetic field exerts a force on the individual electrons in the wire, which causes a current to flow.
- The potential difference in the case of moving a wire through a magnetic field is produced by the work done on the charges by whatever is pushing the wire through the field.

- The EMF (or voltage) depends on the magnetic field strength, B, the length of the wire in the magnetic field, l, and the velocity of the wire in the field, $EMF=Blv$.

## Review

1. Which of the following units are equivalent to those of EMF produced in a generator?
    1. T·m/s
    2. V·m2/s
    3. J/s
    4. A·Ω
    5. T·m
2. A straight wire 0.500 m long is moved straight up through a 0.400 T magnetic field pointed in the horizontal direction. The speed of the wire is 20.0 m/s.
    1. What EMF is induced in the wire?
    2. If the wire is part of a circuit with a total resistance of 6.00 Ω, what is the current in the circuit?
3. A straight wire, 25.0 m long, is mounted on an airplane flying at 125 m/s. The wire moves perpendicularly through earth’s magnetic field (B=5.00×10−5 T). What is the EMF induced in the wire?
4. A straight wire, 30.0 m long, moves at 2.00 m/s perpendicularly through a 1.00 T magnetic field.
    1. What is the induced EMF?
    2. If the total resistance of the circuit is 15.0 Ω, what is the current in the circuit?

## Explore More

Use this resource to answer the questions that follow.

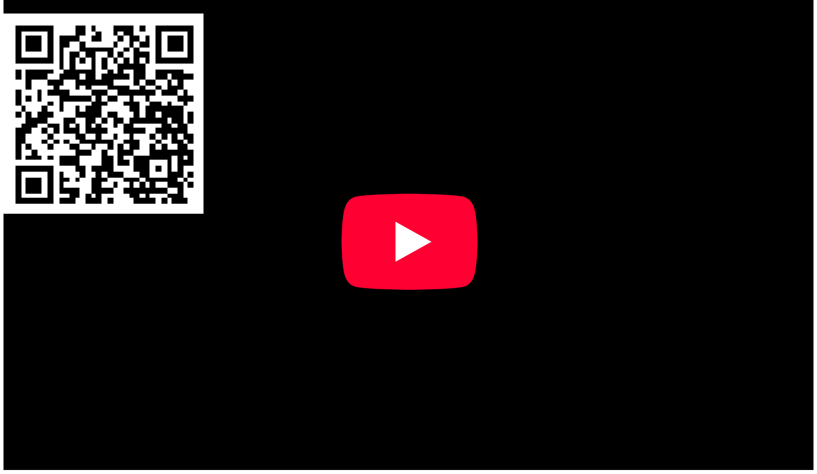
1. We have been discussing the process of generating electricity by moving a wire through a magnetic field. What happens if the wire is held steady and the magnetic field moves instead?
2. When a loop of wire is turned circularly in a magnetic field, what type of current is produced?

## Additional Resources

Interactive: AC Transformer

Real World Application: Controlling Traffic In Real Time

Videos:



Study Guide: Magnetism Study Guide