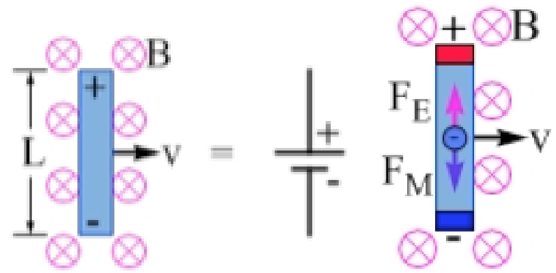
CH 20-2 – Motional EMF

Important Ideas

- If a piece of metal is moving through a magnetic field, the magnetic force on electrons causes the metal to become polarized. In the example shown below, the left-hand rule gives a magnetic force on an electron that is downward, causing the bottom of the metal to become negatively charged, leaving the top of the metal positively charged.

  The piece of metal is like a battery that is not connected to a circuit. The voltage across the metal is an emf. An electron in the metal is in equilibrium, with the electric force (due to charges on the ends of the metal) balanced by the magnetic force (due to the magnetic field). Thus,

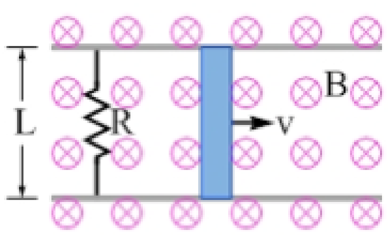
$$
\begin{aligned}
F_{mag} &= F_{elec} \\
qvB &= qE \\
vB &= E \\
vB &= \frac{\varepsilon}{L}
\end{aligned}
$$

  Thus, the emf across the metal is

$$\varepsilon = vBL$$

  This is called a *motional emf* because it is due to the motion of the metal through a region with magnetic field. If the metal is not moving, then the emf across its ends is zero.

- If the piece of metal slides on metal rails so that a conductor is connected from the + side to the − side of the metal, then there is a circuit and current flows from the + terminal around the circuit to the − terminal of the moving piece of metal.

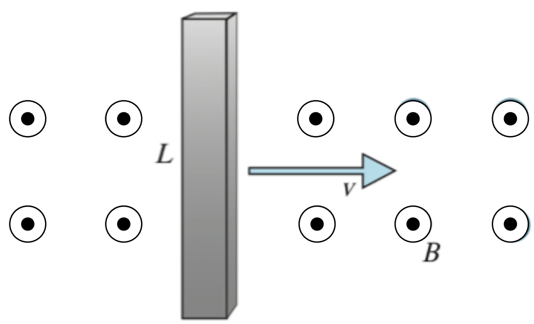
  The current in the circuit is given by Ohm's Law, $I = \frac{\varepsilon_0}{R}$. Thus,

$$I = \frac{vBL}{R}$$

- This creates a magnetic force on the moving piece of metal that is opposite the velocity of the metal. If left alone, it will slow to a stop. This makes sense when you think of the situation in terms of energy. The resistance in the metal converts electric potential energy to thermal energy. Thus, the electric potential energy is "lost." Since the electric potential is a result of the kinetic energy (motion) of the metal, then the metal must slow down. If you want to maintain a constant current, then you have to exert an equal force to the right on the piece of metal. In this case, they electric potential energy supplied by the moving piece of metal is a result of the mechanical work that you do in pulling the metal through the magnetic field.

Examples

1. A wire is moving through space where there is a magnetic field.



   (a) Which end of the wire will be positively charged and which end will be negatively charged?

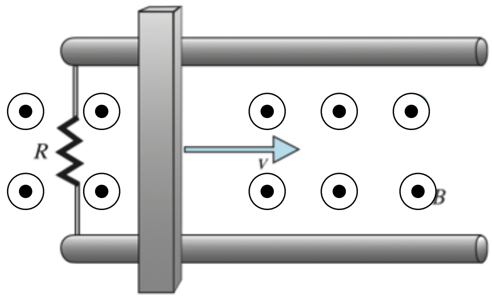
   (b) In what direction will be the electric field inside the wire?

   (c) What is the net force on a free electron inside the wire?

   (d) If the magnetic field is 0.05 T and the wire is 5 cm long, what speed is necessary to produce an emf of 1 mV across the ends of the wire?

   (e) Will the wire continue moving at a constant velocity or will it slow down or speed up?

2. A wire is moving on frictionless rails in a uniform magnetic field. The wire is part of a complete circuit with total resistance R.



(a) Which end of the wire will be positively charged and which end will be negatively charged?

(b) In what direction will current flow around the circuit?

(c) If the magnetic field is 0.05 T and the wire is 5 cm, what speed is necessary to produce an emf of 1 mV across the ends of the wire?

(d) If the resistance is 20 Ω, what is the current in the circuit?

(e) What is the magnitude and direction of the magnetic force on the moving wire?

(f) Will the wire continue moving at a constant velocity or will it slow down or speed up?

(g) Will the current in the circuit increase, decrease, or remain constant?

(h) How can you induce a constant current in the circuit?