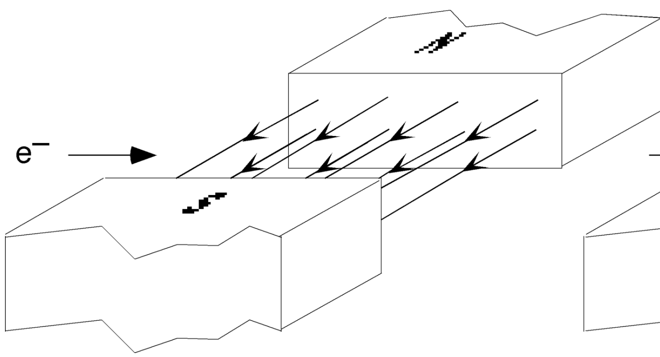
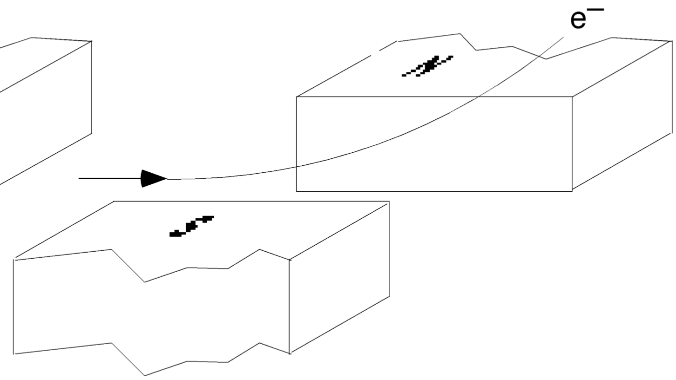
PhyzGuide: Introduction to Induction

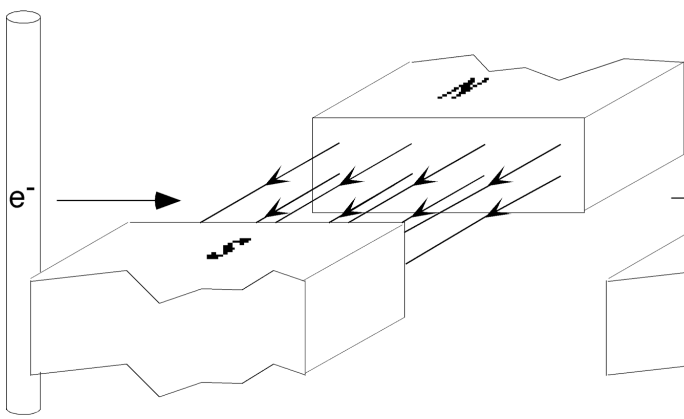
Electromagnetic induction is a process in which a voltage is generated between the ends of a wire when the wire is in a changing magnetic field. A simple example of induction occurs when a wire moves through a magnetic field. In this case, try to see induction as a simple result of the magnetic force on a moving charged particle.



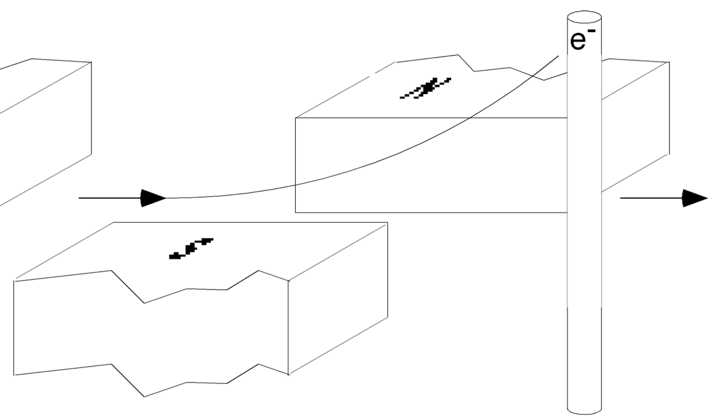
1. Consider an electron moving to the right toward a magnetic field directed out of the page.



2. The electron is deflected upward by the Lorentz force (the magnetic force exerted on a charged particle moving through a magnetic field).



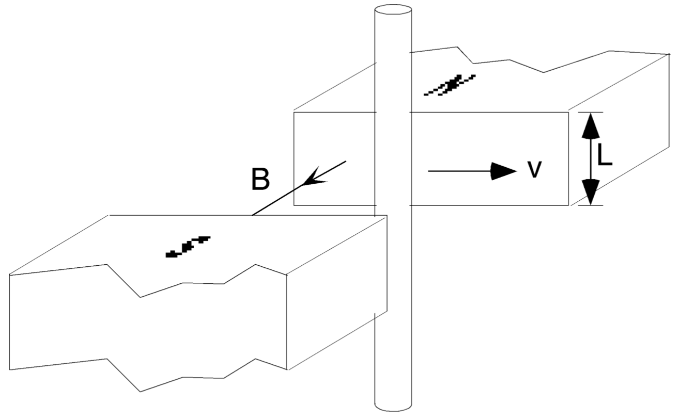
1. Consider a *free* electron *in a conducting wire* moving to the right toward a magnetic field directed out of the page.



2. The electron *in the wire* is deflected upward by the Lorentz force (the magnetic force exerted on a charged particle moving through a magnetic field).

More than one electron will participate in this process, so there will be an accumulation of negative charge at the top of the wire and an equal accumulation of positive charge at the bottom. The electric potential that results from this separation of charge is called induced electromotive force or **induced emf**.

Notice that the wire, its velocity, and the magnetic field are mutually perpendicular. This configuration gives the maximum induced emf. If any two of the three directions are parallel, there is no induced emf.

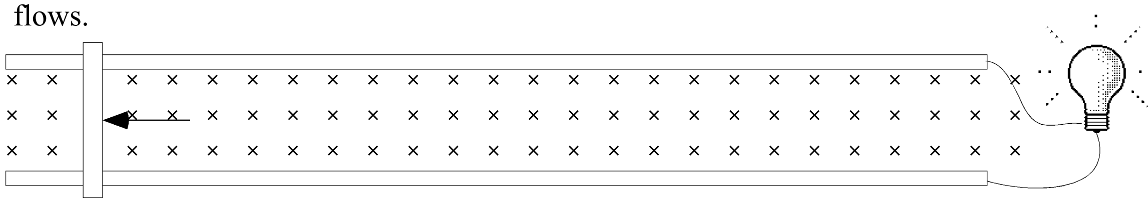


The magnitude of the induced emf ε is

$\varepsilon = BLv$

where B is the strength of the magnetic field, L is the effective length of wire in the magnetic field, and v is the speed of the wire.

It is theoretically possible to connect a circuit as shown below. A conducting bar is placed across two long conducting rails. A magnetic field exists between the rails. When the bar is moved along the rails, an emf is induced through the length of the bar (and thus, there is a potential difference between the rails). The rails are connected by some external conducting path that completes the circuit, and current flows.



In this circuit, electrons in the bar are pushed downward by the Lorentz force, so electrons travel counter-clockwise in this circuit.

This means that conventional current flows clockwise in this circuit.

But think about this: current is moving upward through the sliding bar, and the bar is sliding through a magnetic field. What do you know about the interaction of current and magnetic fields? Will there be a magnetic force on the current-carrying bar?

Indeed there will. And it is directed opposite to the bar's velocity.

Example Problem

In the diagram above, the magnetic field is 0.2 T, the distance between the rails is 0.6 m and the speed of the bar is 15 m/s. The light bulb has a resistance of 6 Ω.

a. What is the induced emf?

$\varepsilon = BLv$
$\varepsilon = 0.2\ \text{T} \cdot 0.6\ \text{m} \cdot 15\ \text{m/s}$
$\varepsilon = 1.8\ \text{V}$

b. What is the current in the circuit?

$I = \varepsilon/R$
$I = 1.8\ \text{V} / 6\ \Omega$
$I = 0.3\ \text{A}$

c. How much force is required to keep the bar at constant speed?

$F = ILB$
$F = 0.3\ \text{A} \cdot 0.6\ \text{m} \cdot 0.2\ \text{T}$
$F = 0.036\ \text{N}$

