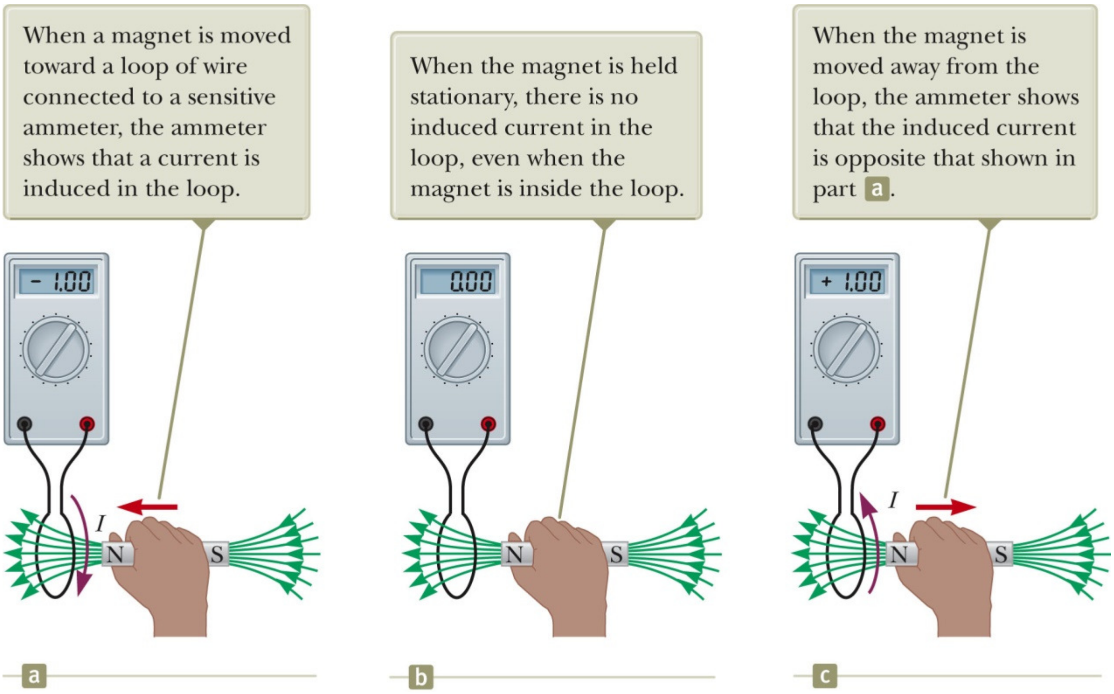
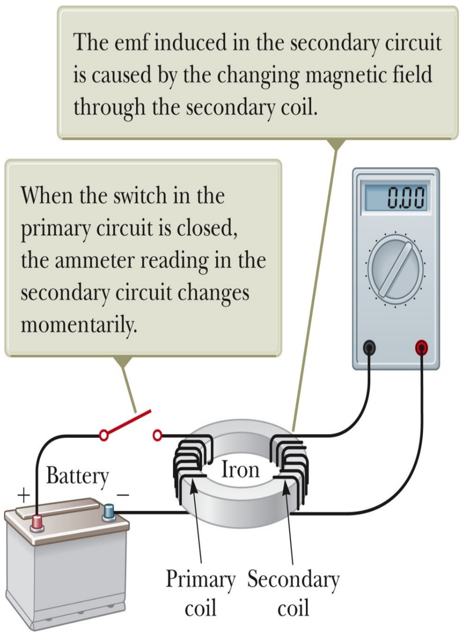
Chapter 31

Faraday's Law

31.1 Faraday's Law of Induction



Experimentalists, Faraday and Henry et al., found that an emf is induced in the circuit if the magnetic flux through the surface bounded by the circuit is changed.



❖ The emf induced in a circuit is directly proportional to the time rate of change of the magnetic flux through the circuit.

Mathematically,

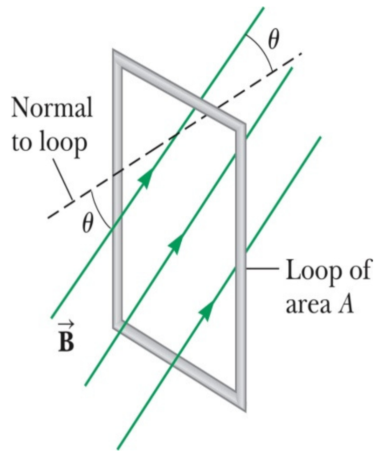
$$\varepsilon = -\frac{d\Phi_B}{dt}$$

Remember, Φ_B is the magnetic flux through the circuit and is found by:

$$\Phi_B = \int \vec{\mathbf{B}} \cdot d\vec{\mathbf{A}}$$

If the circuit consists of N loops, all of the same area, and if Φ is the flux through one loop, an emf is induced in every loop and Faraday's law becomes

$$\varepsilon = -N\frac{d\Phi_B}{dt}$$



❖ Assume a loop enclosing an area A lies in a uniform magnetic field.

The magnetic flux through the loop is

$$\Phi_B = BAcos_\theta$$

Then, the induced emf can be written as:

$$\epsilon = -\frac{d}{dt}(BAcos_\theta)$$

Ways of Inducing an emf:

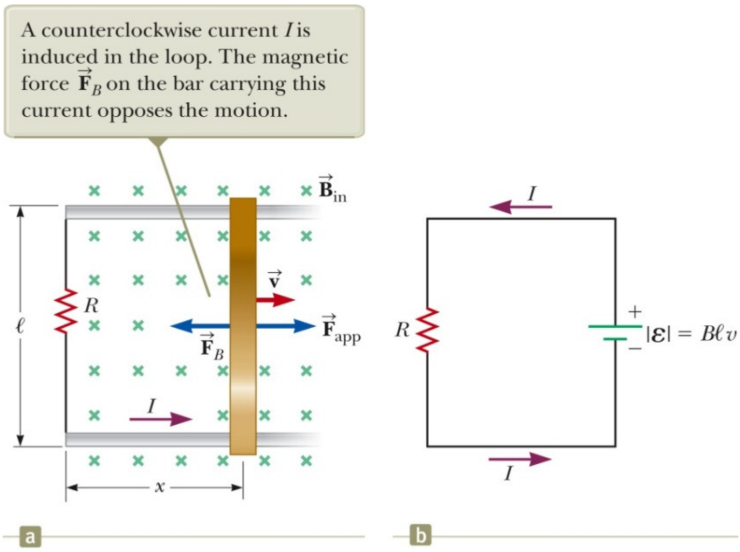
✓ The magnitude of the magnetic field can change with time.
✓ The area enclosed by the loop can change with time.
✓ The angle between the magnetic field and the normal to the loop can change with time.
✓ Any combination of the above can occur.

Example1 :

A coil consists of 200 turns of wire. Each turn is a square of side 18 cm, and a uniform magnetic field directed perpendicular to the plane of the coil is turned on. If the field changes linearly from 0 to 0.50 T in 0.80 s, what is the magnitude of the induced emf in the coil while the field is changing?

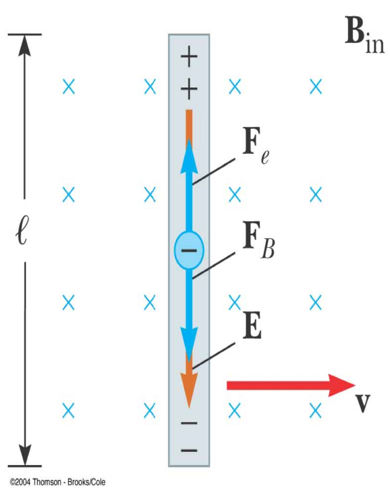
31.2 Motional emf

Motional emf is the emf induced in a **conductor moving through a <u>constant magnetic field.</u>**



I-

A straight electrical conductor of length moving with a velocity **v** through a uniform magnetic field **B** directed perpendicular to **v**. Due to the magnetic force on electrons, the ends of the conductor become oppositely charged. This establishes an electric field in the conductor. **In steady state, the electric and magnetic forces on an electron in the wire are balanced.**



$$F_B = F_E$$

$$qvB = qE$$

Or, $$E = vB$$

Also, the electric field produced in the conductor is related to the potential difference across the ends of the conductor:

$$\Delta V = El = Blv$$

=➔A potential difference is maintained between the ends of the conductor as long as the conductor continues to move through the uniform magnetic field.

II-

Using Faraday's law, and noting that x changes with time at a rate dx/dt = v, we find that the induced motional emf is:

$$\epsilon = -\frac{d\Phi_B}{dt} = -\frac{d}{dt}(Blx) = -Bl\frac{dx}{dt} = -Blv$$

If the resistance of the circuit is R, the magnitude of the induced current is:

$$I = \frac{|\epsilon|}{R} = \frac{Blv}{R}$$

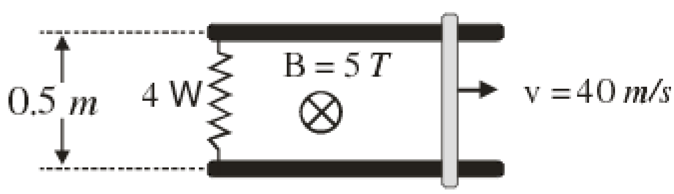
III-

- The applied force does work on the conducting bar.
- The change in energy of the system during some time interval must be equal to the transfer of energy into the system by work.
- The power input is equal to the rate at which energy is delivered to the resistor.

$$P = F_{app.}v = (IlB)v = \left(\frac{Blv}{R}\right)(lB)v = \frac{B^2l^2v^2}{R} = \frac{\epsilon^2}{R}$$

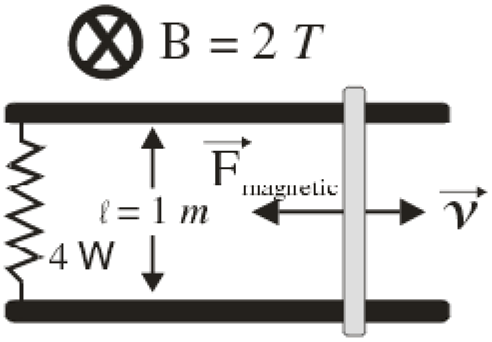
Example2:

Find the current I in following circuit.



Example3:

Calculate the magnetic force ($F_{Magnetic}$) in the following figure exerted on the bar when it moves to the right at a constant speed of 200 cm/s
in a uniform 2.0 T magnetic field directed into the page.



Example4:

A bar of length l =1m moves on two horizontal frictionless rails with a constant speed of 3 m/s in a magnetic field B = 4T directed perpendicularly downward into the paper as shown in the figure. If the applied force required to move the bar to the right is 6 N. **Find the resistance R.**