Induced E.M.F.

Induced EMF

- Faraday showed that moving a wire in a magnetic field induces a current in that wire.
- As work is done in moving the charge from one end to the other, an electric potential exists: induced emf (voltage)

- The induced emf (and current) only occurs when the displacement is at right angles to the magnetic field.
- The induced emf (and current) immediately stops when the velocity is zero.

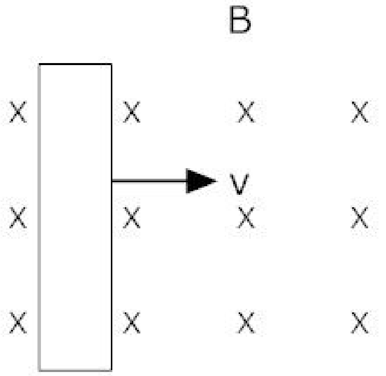
- The strength of the emf produced depends on:
  - The speed of the movement
  - The strength of the magnetic flux density
  - Number of turns in the coil (number of wires)
  - The area of the coil

Magnetic Flux

- The number of magnetic field lines passing through an area.

- Faraday realized that the magnitude of the induced emf was not proportional to the rate of change of the magnetic field
- The magnitude of the induced emf is related to the rate of change of magnetic flux (or flux linkage for more than one wire)

Consider a wire of length *l*, moving with velocity *v*, perpendicular to a magnetic field *B*.

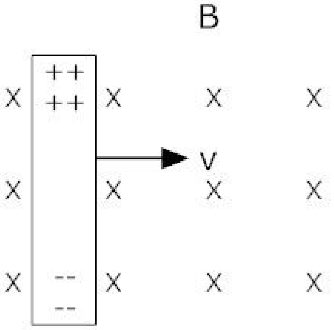


X = B into page

Since charges are moving in a magnetic field, there is a force.

$$F_B = qvB\sin\theta \qquad \theta = 90^{\mathrm{o}}$$

In our case force (on positive charges) is up.



This generates an electric field, and thus a force.

$$F_E = qE$$

At some point these two forces will be equal and the charges stop moving.

$$F_E = F_B$$
$$qE = qvB$$

but $E = \dfrac{\Delta V}{\Delta x}$ so $\dfrac{\Delta V}{\Delta x} = vB$

or $\boxed{\varepsilon = Bvl}$

Faraday related the emf to magnetic flux, which is an area.

$$\boxed{\Phi = BA\cos\theta}$$

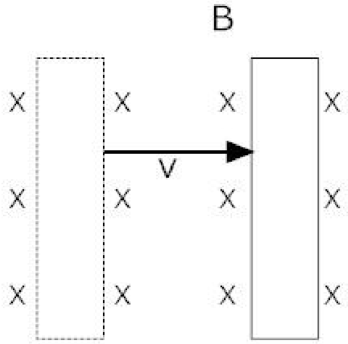
Units: weber, Wb

Magnetic flux

Magnetic field

Area

Magnetic flux is a measure of the number of lines of magnetic force passing through an area.



In time *Δt*, the wire moves a distance *Δx*

Therefore, it covers an area of *lΔx*

So… in *Δt*

$$\varepsilon = \frac{Bl\Delta x}{\Delta t} = \frac{BA}{\Delta t}$$

$$\therefore \quad \varepsilon \propto \frac{\Delta\Phi}{\Delta t}$$

if we have more than 1 wire (a coil), we have

$$\varepsilon \propto N\frac{\Delta\Phi}{\Delta t}$$

where *N* is the number of wires (in the coil)

Faraday’s Law

- The magnitude of the induced emf in a circuit is directly proportional to the rate of change of magnetic flux or flux-linkage.

Heinrich Lenz

- In 1834, Russian physicist Lenz applied the Law of Conservation of Energy to determine the direction of the induced emf for all types of conductors.

Lenz's Law

- The direction of the induced emf is such that the current it causes to flow opposes the change producing it.
- In other words, the resulting emf is in the opposite direction of the motion.

- Combining Faraday's law and Lenz's law then gives us equation for induced emf.

$$\varepsilon = -\frac{\Delta\Phi}{\Delta t}$$

$$\boxed{\varepsilon = -N\frac{\Delta\Phi}{\Delta t}}$$

Example 1

- The magnetic flux through a coil of wire containing 5 loops, changes from -25 Wb to 15 Wb in 0.12 s. What is the induced emf in the coil?

$$\varepsilon = -N\frac{\Delta\Phi}{\Delta t}$$

$$= -(5)\frac{(15\,Wb - -25\,Wb)}{0.12\,s} \quad = -1700\ \mathrm{V}$$

Example 2

- The wing of a jumbo jet is 9.8 m long. It is flying at 840 kmh^{-1}. If it is flying in a region where the earth's magnetic field has a vertical component of $7.2\mathrm{x}10^{-4}$ T, what potential difference could be produced across the wing?

$$v = 840\ \mathrm{kmh}^{-1} = 233.3\ \mathrm{ms}^{-1}$$

$$\varepsilon = Bvl = (7.2\mathrm{x}10^{-4}\ T)(9.8\ \mathrm{m})(233.3\ \mathrm{ms}^{-1}) = 1.6\ \mathrm{V}$$