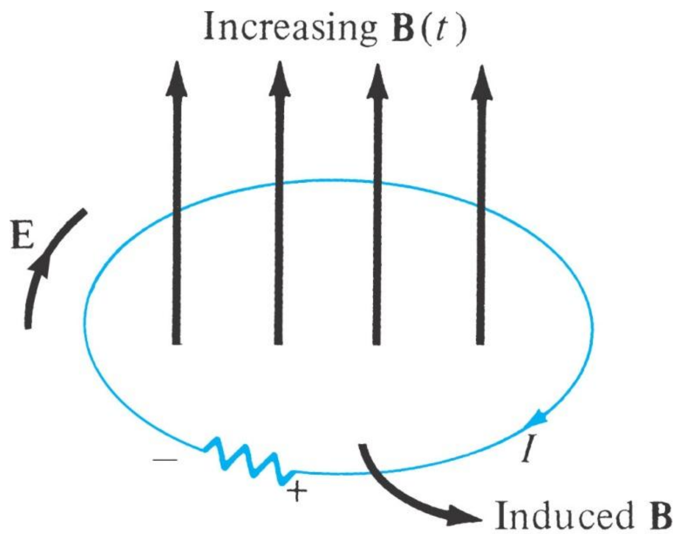
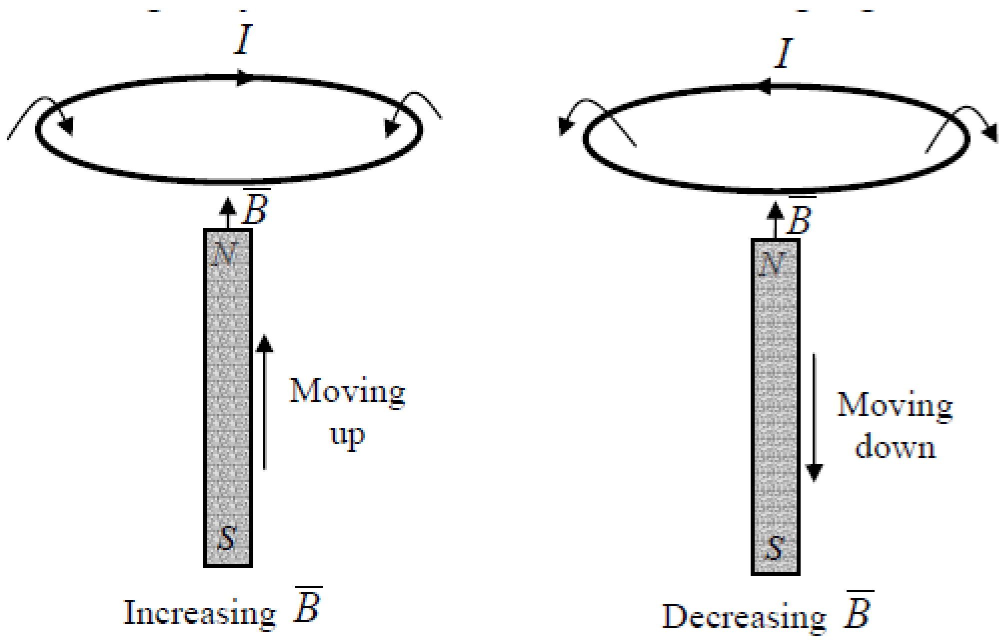
FARADAY'S INDUCTION LAW

1) A stationary circuit in a time-varying field:
   (Transformer emf)



It is well known that current carrying conductor produces a magnetic field, the inverse of this is also true.

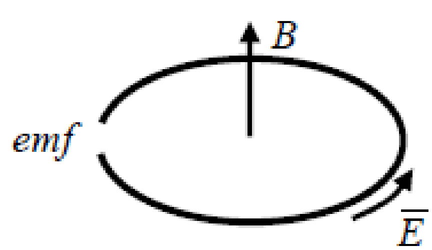
A magnetic field can produce a current in a closed circuit but the magnetic flux linkage by the circuit must be changing with the time.



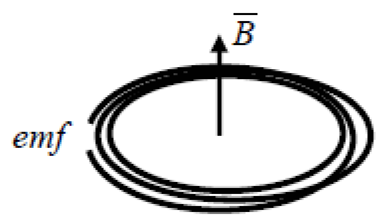
Refering to the above figure the magnetic field due to the induced current opposes the magnet moment, thus moving the magnet up and down produces AC current.

If the loop is open circuited an *emf* apperas at its terminals. i.e.

$$emf = V_{emf} = -\frac{d\psi}{dt} \quad ....(1)$$



Where Ψ is the total flux linkage. If the loop has *N* turns:



$$v_{emf} = -N\frac{d\psi}{dt}$$

The *emf* induced in the loop is equal to the *emf* producing field $\bar{E}$, thus;

$$v_{emf} = \oint \bar{E}.d\bar{l}$$

The total flux through a circuit is equal to the normal component of the flux density $\bar{B}$ over the surface bounded by the circuit, i.e:

$$\psi = \iint_{S} \bar{B}.d\bar{s} \quad \ldots\ldots\ldots\ldots\ldots(2)$$

Where *S* is the surface bounded by the closed circuit.
From (1) and (2)

$$v_{emf} = -N \frac{d}{dt} \iint_S \bar{B}.d\bar{s}$$

$\bar{B}$: flux in Tesla (Wb/m^2).

t: time in seconds.

$d\bar{s}$: surface element in m^2.

If the circuit is stationary or fixed, then

$$v_{emf} = -N \iint_S \frac{\partial \bar{B}}{\partial t}.d\bar{s}$$

2) Moving Conductor in a Magneric Field:
   (Motional emf)

Lorentz Force $\bar{F}$ on a particle of charge Q moving with a velocity $\bar{v}$ in a magnetic field $\bar{B}$ is:

$$\bar{F} = Q(\bar{u}\ X\ \bar{B})$$

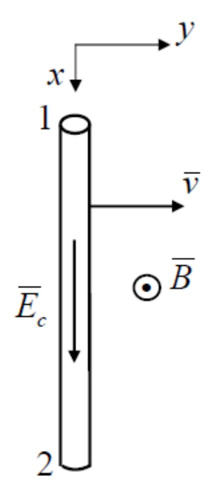
$$\frac{\bar{F}}{Q} = (\bar{u}\ X\ \bar{B}) = \bar{E}$$

$$v_{emf} = \int_1^2 \bar{E}.d\bar{l}$$

$$v_{emf} = \int_1^2 \bar{u}X\bar{B}.d\bar{l}$$

For a closed circuit moving in a magnetic field with velocity $\bar{u}$:

$$v_{emf} = \int_1^2 \bar{u}X\bar{B}.d\bar{l}$$



3) General Case of Induction

The total emf induced in a closed circuit due to the time varying firld and moving by velocity $\bar{u}$ is given by:

$$\bar{v}_{emf} = \int \bar{u} X \bar{B} . d\bar{l} - \iint_{S} \frac{d\bar{B}}{dt} . d\bar{s}$$

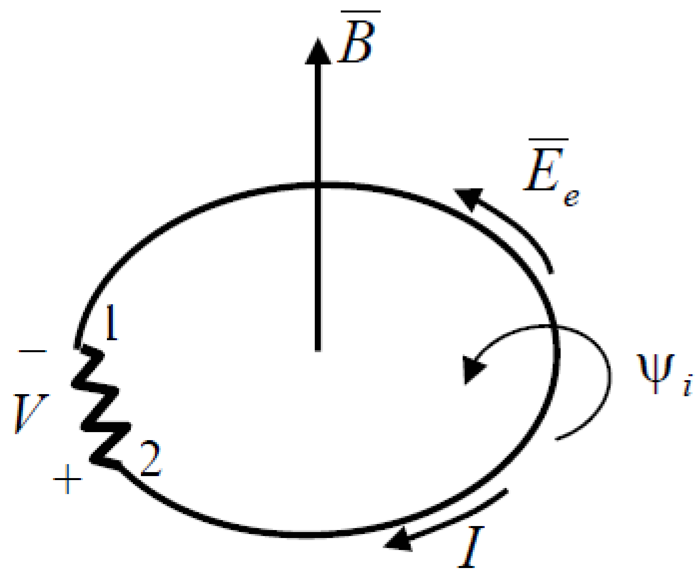
emf due to motion emf due to time varying $\bar{B}$

Sign Convention (*Lenz's Law*):

1) Transformer emf

a) Increasing $\bar{B}$, increases Ψ_i.

b) The induced current produces a flux Ψ_i trying to compensate for the increase of the flux due to $\bar{B}$.



c) $\overline{E}_e$ is the induced potential:

$$V = \int_2^1 \overline{E}_e . d\overline{l} = -A\frac{d\overline{B}}{dt}$$

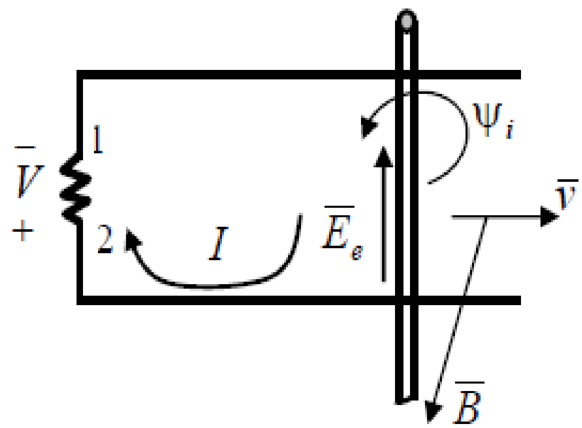
2) Motional emf

a) Ψ_i increases do to the movement of the bar.

b) The induced current prodeces a flux Ψ_i trying to compensate for thr increase of the flux due to $\overline{B}$.

c) $v = \int_2^1 \overline{E}_e . d\overline{l} = \overline{u} X \overline{B}\, l = -B\frac{\partial A}{\partial t}$

Where A is the area of the circuit.



Source:http://opencourses.emu.edu.tr/pluginfile.php/1696/mod_resource/content/0/

Electromagnetic_Induction.pdf