Induction

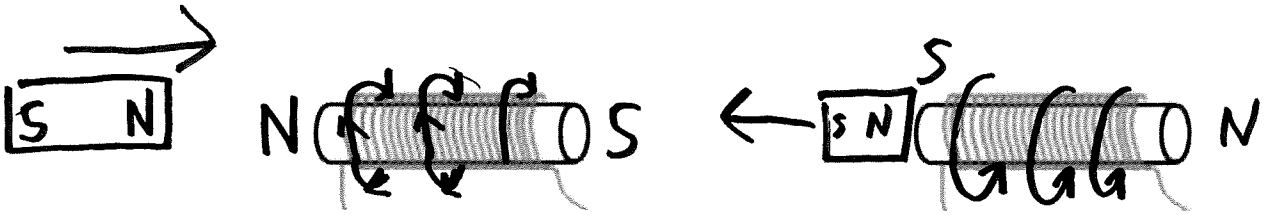
It was discovered that a wire with current flowing through it created a magnetic field, the next question was: Could a magnetic field cause current to flow in a wire?

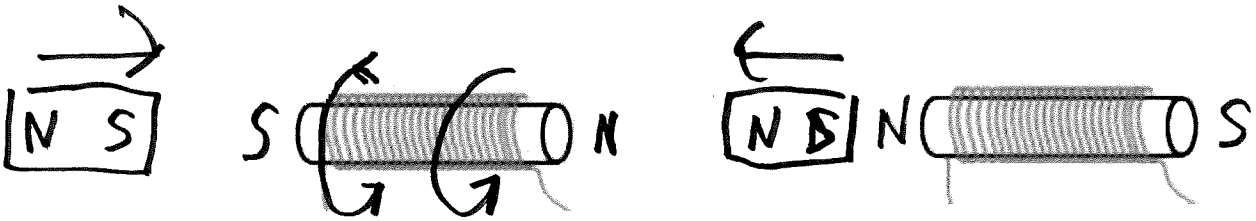
Another way to say this is: Could a magnetic field generate an EMF?

Michael Faraday discovered it was possible with a moving magnetic field.

To determine the direction of the induced current we use Lenz's Law:

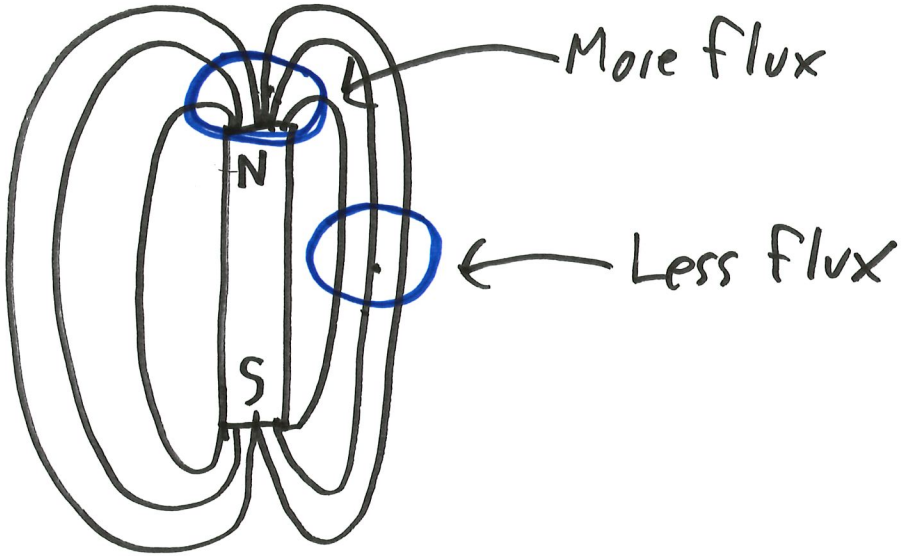
Induced current flows in the direction which opposes the change causing it.

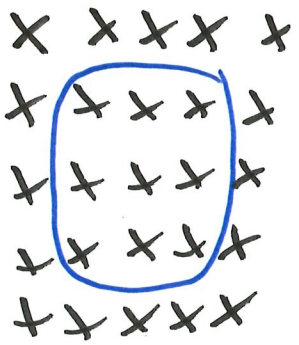




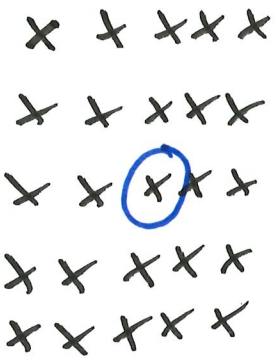
In order to calculate the EMF generated we need to use the idea of magnetic flux.

Magnetic Flux: # of magnetic field lines passing through a coil



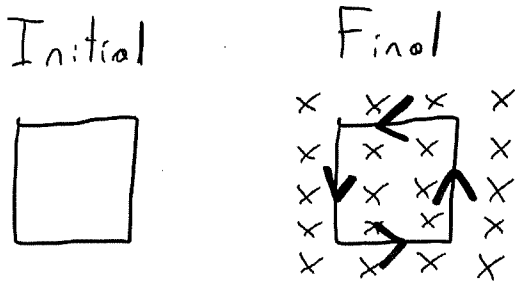


More flux



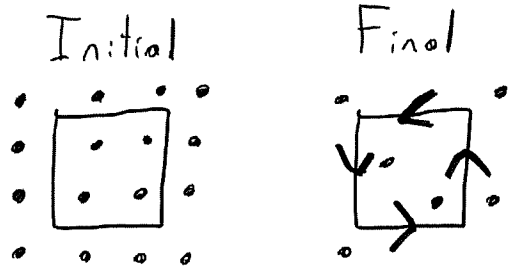
Less flux

Symbol Φ



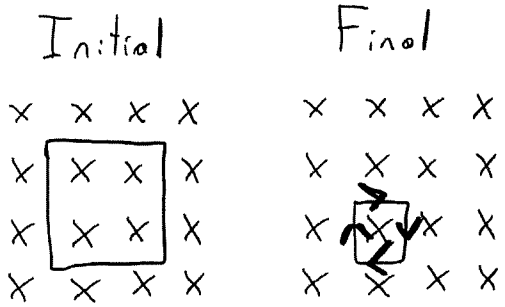
Change in Φ: More into page

How to oppose: More out of page



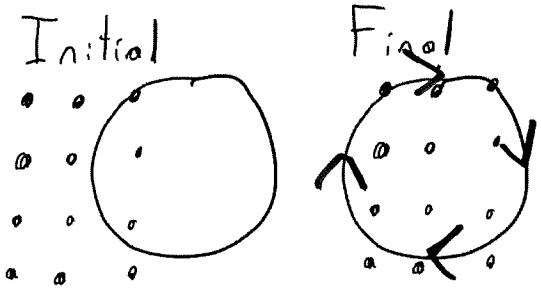
Change in Φ: Less out of page

How to oppose: More out of page



Change in Φ: Less into page

How to oppose: More into page



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How to oppose: More into page

Magnetic flux perpendicular to a magnetic field can be calculated as

$$\Phi = BA$$

A ← area; B ← magnetic field strength

Units are $T m^2$ or Webers (Wb)

Example: A square loop of wire is perpendicular to a 1.50 T magnetic field. If each side of the wire is 2.10 cm what is the magnetic flux through the loop?

0.021 m

$A = (0.021)^2 = 0.000441 m^2$

$\Phi = (1.5)(0.000441) = 0.000662$ Wb

The EMF is induced on a loop of wire by a changing flux

$$\mathcal{E} = \left| \frac{\Delta \Phi}{+} \right|$$

If there are several loops of wire the EMF generated by each loop adds together so total EMF is

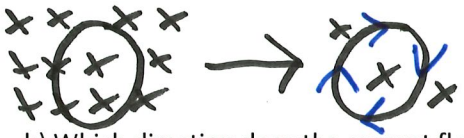
$$\mathcal{E} = \left| N \frac{\Delta \Phi}{+} \right|$$

N ← # of loops

Example: A circular loop of wire with radius 2.5 cm is placed in a magnetic field B=0.020 T into the page. The field is reduced to 0.010 T into the page in 0.10 seconds.

$A_{red} = \pi r^2 = \pi (0.025)^2 = 0.001963 m^2$

a) What is the average induced EMF?



b) Which direction does the current flow?

Change: Less into

Oppose: More into

Clockwise

$\Delta \Phi = \Phi_f - \Phi_i$

$\Phi = (0.001963)(0.010) - (0.001963)(0.020)$

$= -1.96 \times 10^{-5}$ Wb

$\mathcal{E} = \left| \frac{(-1.96 \times 10^{-5} \text{ Wb})}{0.10} \right|$

$= 1.96 \times 10^{-4}$ V