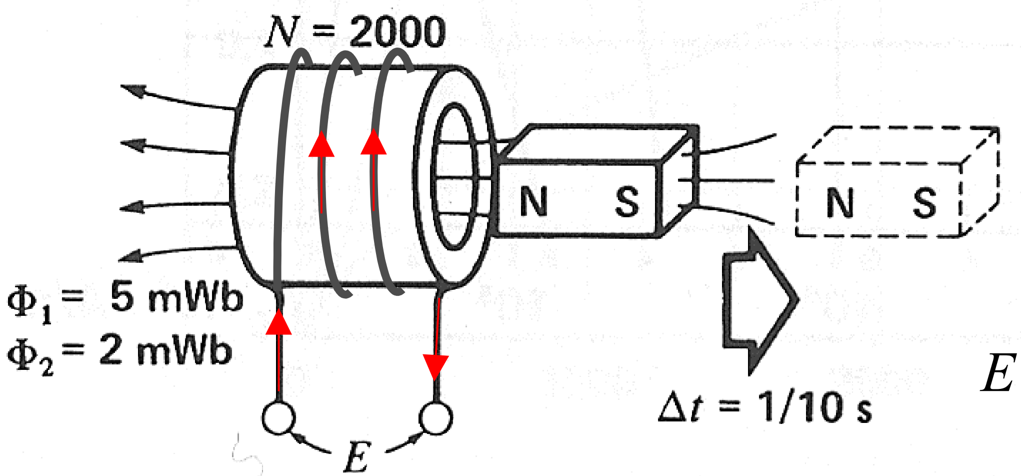
Faraday's Law of Electromagnetic Induction

1. If the flux linking a loop (or turn) varies as a function of time, a voltage is induced between its terminals.
2. The value of the induced voltage is proportional to the rate of change of flux

$$E = -N\frac{d\phi}{dt}$$

The "-" sign indicates that the inducted E has a tendency to decrease the change of flux

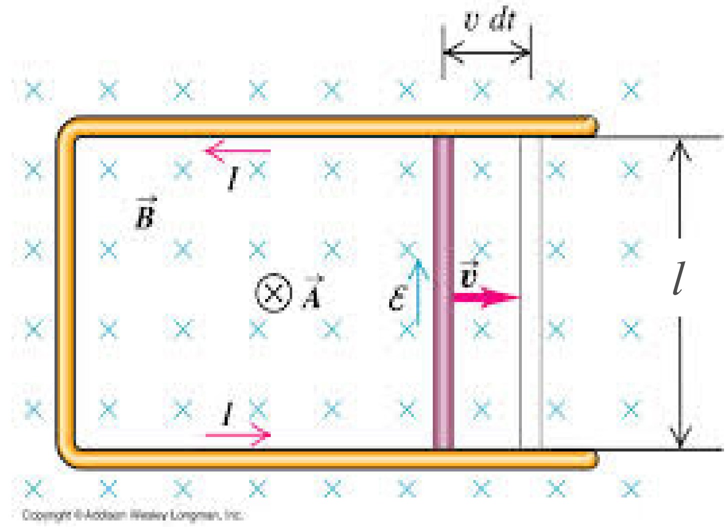


$$E = -2000 \times \frac{0.002 - 0.005}{0.1}$$

$$= 60\,\mathrm{V}$$

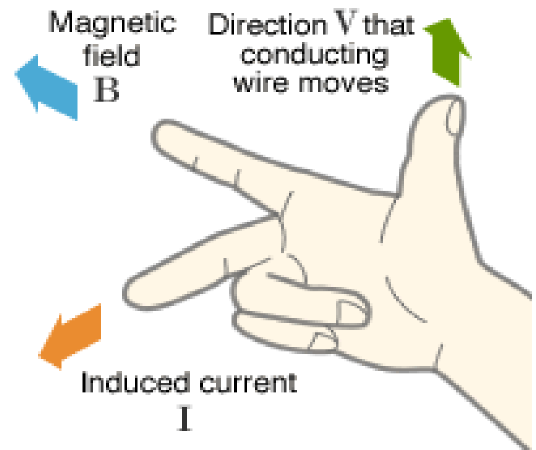
Voltage Induced in a Conductor

- Conclusion from Faraday's Law
  - Whenever a moving conductor (part of a coil) cuts a magnetic field *B*, a voltage ε is induced across its terminals, which is proportional to its active length *l* and relative speed *v*.



$$\varepsilon = -E = \frac{d\phi}{dt} = \frac{d(BA)}{dt} = \frac{BdA}{dt} = \frac{Blvdt}{dt} = Blv$$

  - The direction of current *I* to be inducted in the conductor follows the right-hand rule.

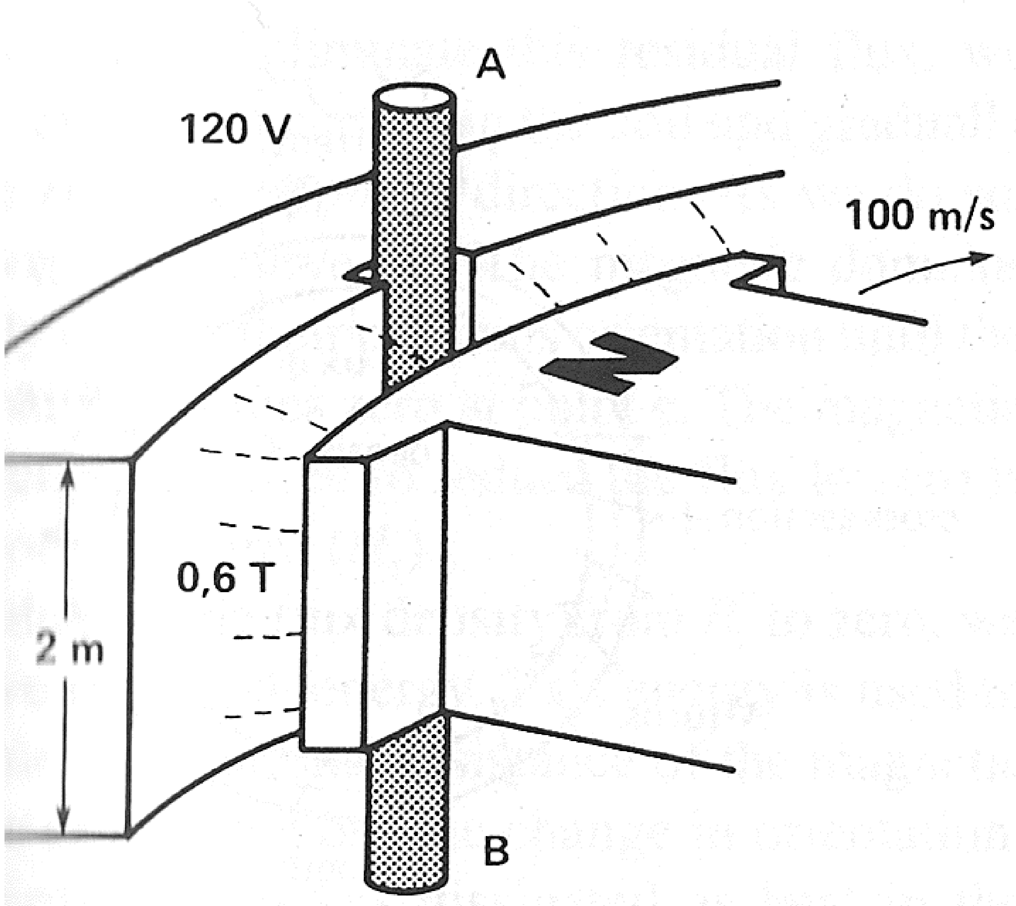


- We may simply use formula ***E =Blv*** to first calculate the magnitude of *E, B* or *v* from any two of them and then judge the direction by the right-hand rule.

Example 3

- B=0.6T, l=2m, v=100m/s.

$$E = Blv = 0.6\times 2\times 100 = 120\ V$$

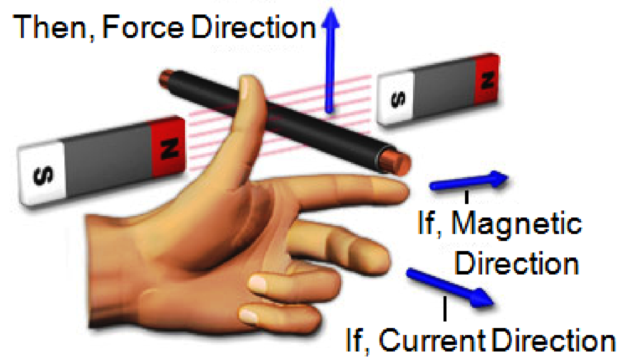


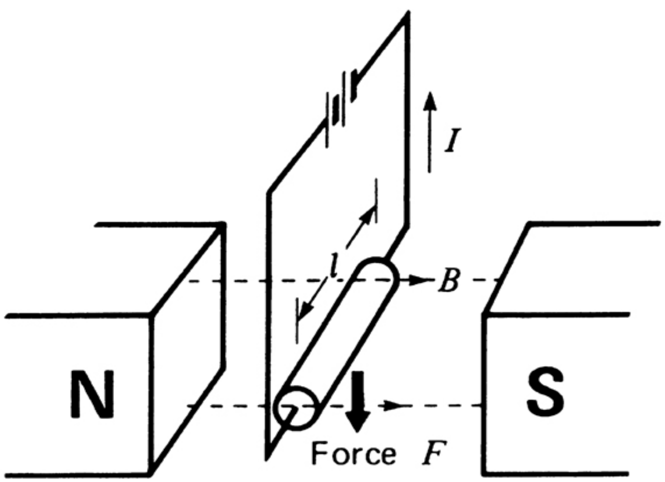
Lorentz Force on a Conductor

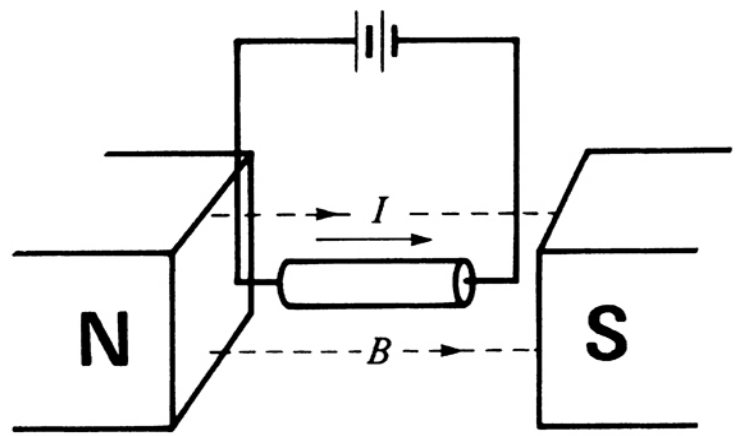
- Also called electromagnetic force, it is the force a current-carrying conductor is subjected to when it is placed in a magnetic field.

$$F = BlI \quad \text{(unit: N)}$$

- The direction of the Lorentz force follows the left-hand rule

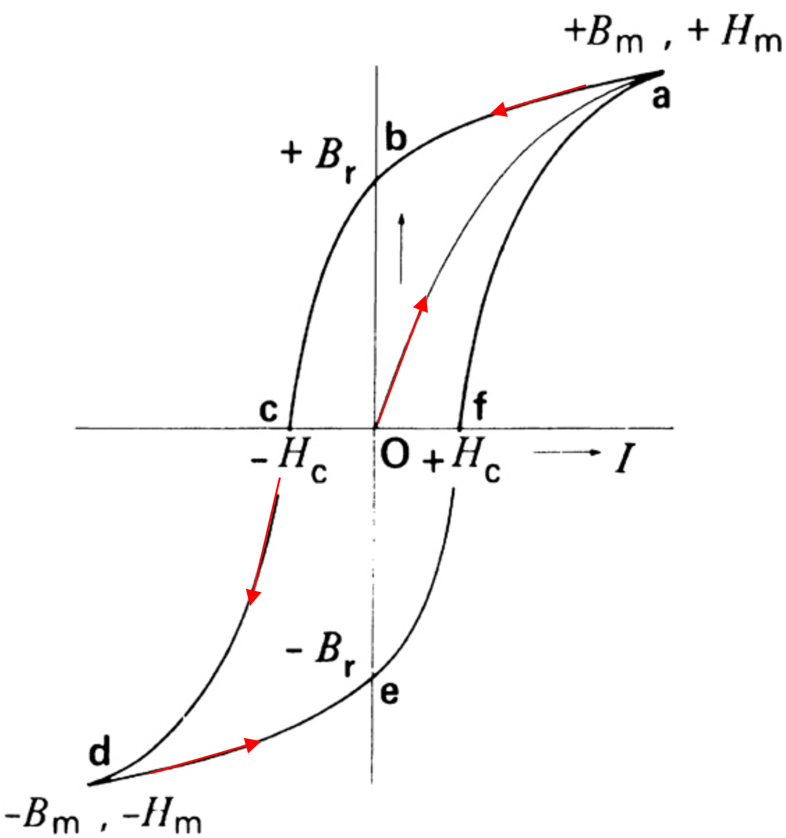


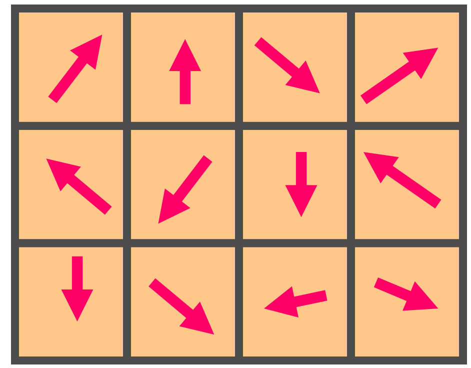




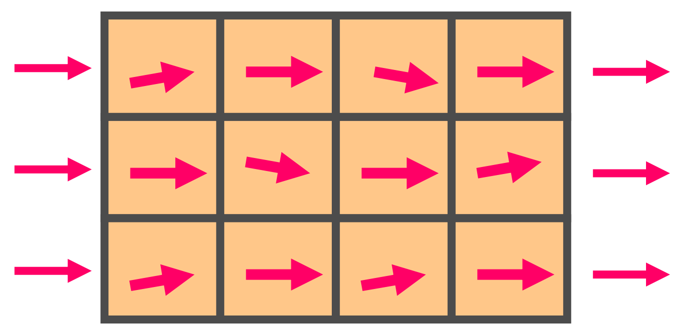
Hysteresis Losses

Hysteresis loop





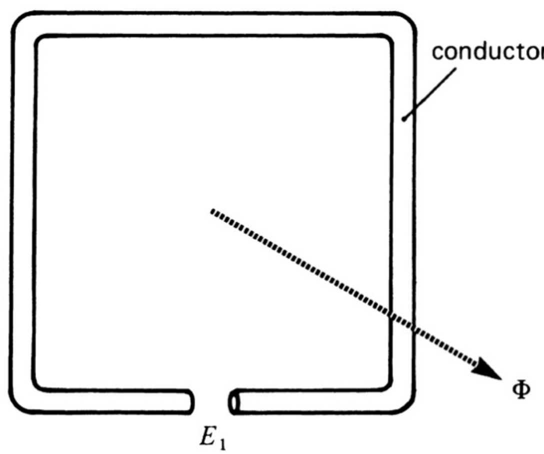
Magnetic domains oriented randomly

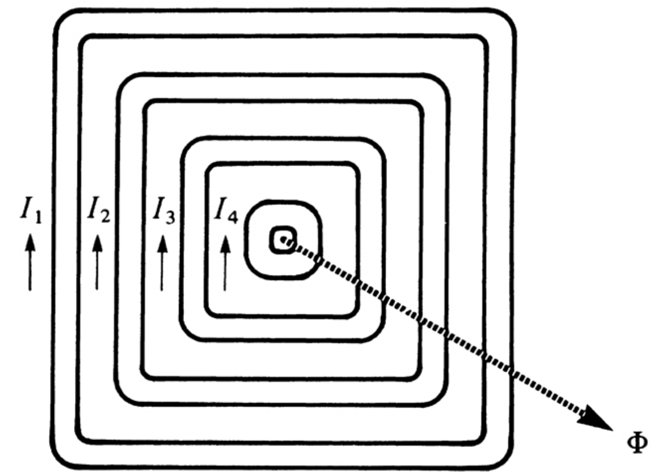


Magnetic domains lined up in the presence of an external magnetic field.

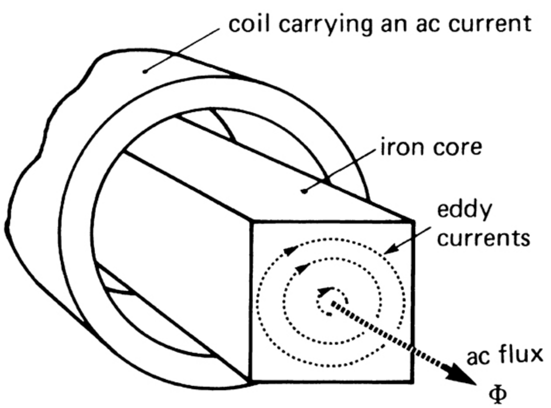
Eddy losses

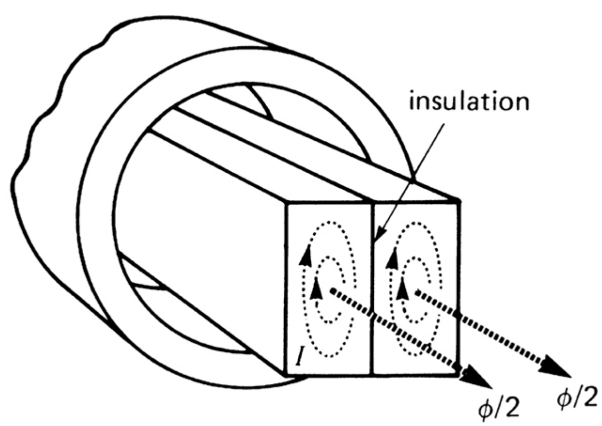
- The cause of eddy currents by an AC flux Φ

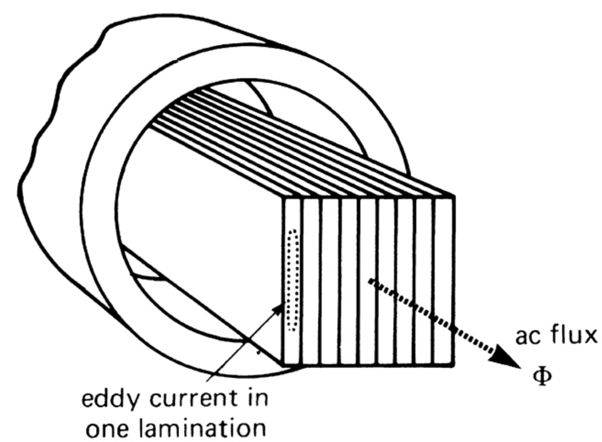




- How to reduce eddy currents

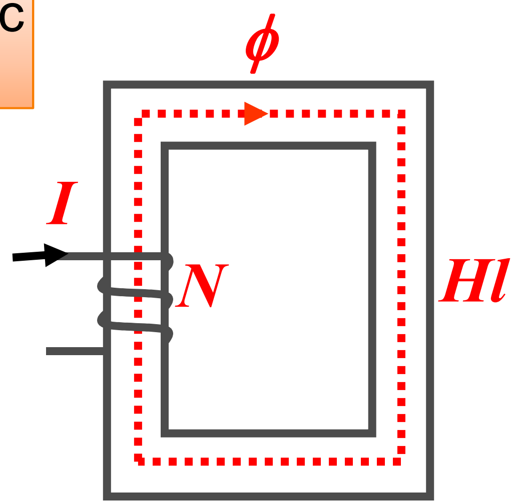


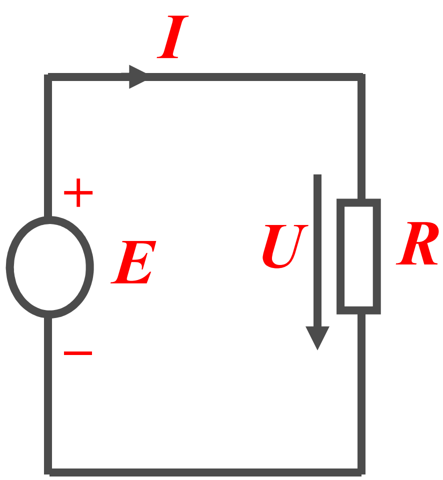




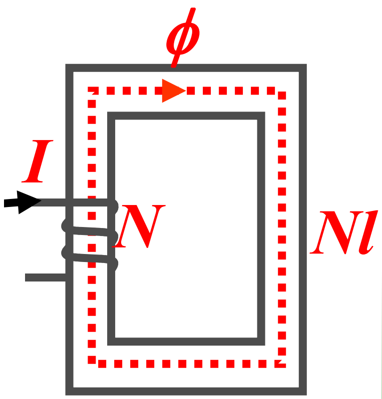
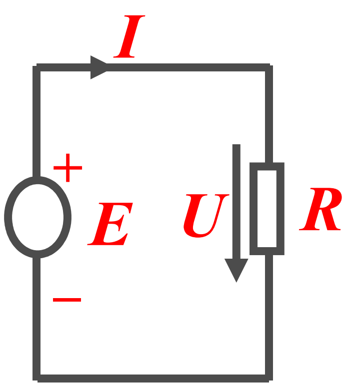
Comparison of Electrical and Magnetic Circuits

Magnetic circuit	mmf $F_m = NI$	Magnetic flux ϕ	Magnetic potential Hl
Electrical circuit	emf E	Current I	Electric potential U





Comparison of Electrical and Magnetic Circuits

Magnetic circuit 	Hopkinson's Law $\phi = \frac{F_m}{R_m}$	Magnetic resistance $R_m = \frac{l}{\mu_r \mu_0 A}$	Magnetic flux density $B = \frac{\phi}{A}$	Ampere's Circuital Law $\sum NI = \sum Hl$	Gauss's Law $\sum \phi = 0$
Electrical circuit 	Ohm's Law $I = \frac{E}{R}$	Electrical resistance $R = \rho \frac{l}{A}$	Current density $J = \frac{I}{A}$	KVL $\sum E = \sum U$	KCL $\sum I = 0$