4. The Faradays law

If a flux passes through a turn of a coil of wire, a voltage will be induced in that turn that is directly proportional to the rate of change in the flux with respect to time:

$$e_{ind} = -\frac{d\phi}{dt} \tag{2.28.1}$$

Or, for a coil having N turns:

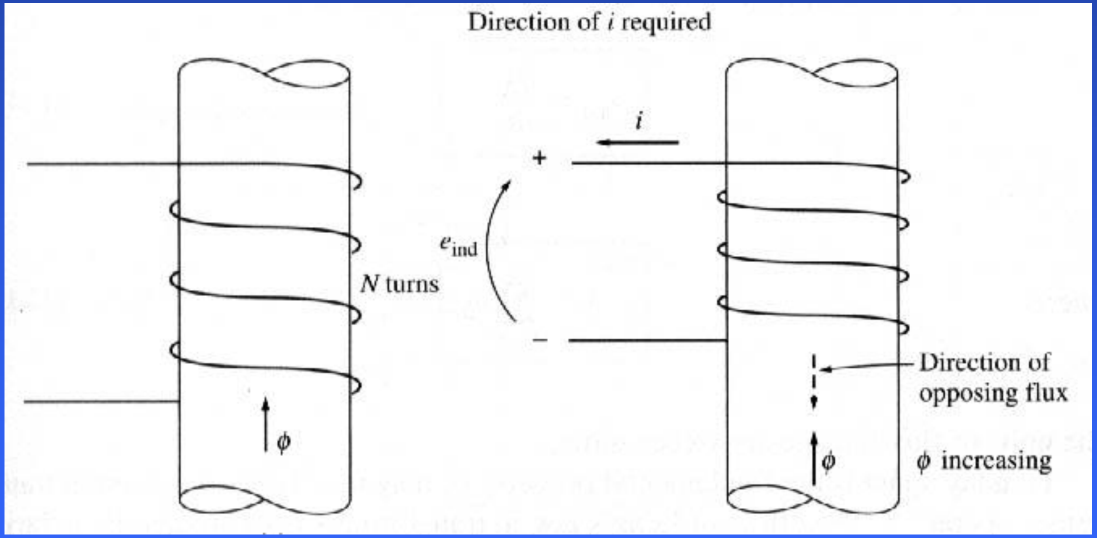
$$\boxed{e_{ind} = -N\frac{d\phi}{dt}} \tag{2.28.2}$$

e_{ind} – voltage induced in the coil
N – number of turns of wire in the coil
ϕ - magnetic flux passing through the coil

4. The Faradays law

The "minus" sign in the equation is a consequence of the Lentz's law stating that: "The direction of the voltage buildup in the coil is such that if the coil terminals were short circuited, it would produce a current that would cause a flux opposing the original flux change".

If the initial flux is increasing, the voltage buildup in the coil will tend to establish a flux that will oppose the increase. Therefore, a current will flow as indicated and the polarity of the induced voltage can be determined.



The minus sign is frequently omitted since the polarity is easy to figure out.

4. The Faradays law

The equation (2.28.2) assumes that the same flux is passing through each turn of the coil. If the windings are closely coupled, this assumption *almost* holds. In most cases, a flux leakage occurs. Therefore, more accurately:

$$e_i = \frac{d\phi_i}{dt} \tag{2.30.1}$$

$$For\ N\ turns:\ e_{ind} = \sum_{i=1}^{N} e_i = \sum_{i=1}^{N} \frac{d\phi_i}{dt} = \frac{d}{dt}\left(\sum_{i=1}^{N} \phi_i\right) \tag{2.30.2}$$

$$\boxed{\Rightarrow\ e_{ind} = \frac{d\lambda}{dt}} \tag{2.30.3}$$

λ - a flux linkage of the coil:

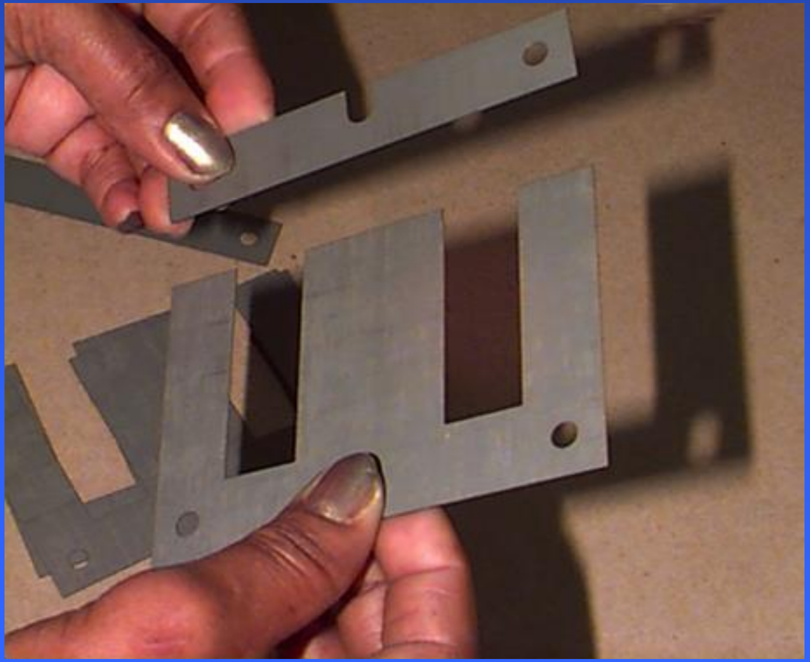
$$\boxed{\lambda = \sum_{i=1}^{N} \phi_i \ \left[Wb - turns\right]} \tag{2.30.4}$$

4. The Faradays law

A nature of eddy current losses:

Voltages are generated within a ferromagnetic core by a time-changing magnetic flux same way as they are induced in a wire. These voltages cause currents flowing in the resistive material (ferromagnetic core) called eddy currents. Therefore, energy is dissipated by these currents in the form of heat.

The amount of energy lost to eddy currents is proportional to the size of the paths they travel within the core. Therefore, ferromagnetic cores are frequently laminated: core consists of a set of tiny isolated strips. Eddy current losses are proportional to the square of the lamination thickness.



4. The Faradays law: Example

Example 1–6. Figure 1–15 shows a coil of wire wrapped around an iron core. If the flux in the core is given by the equation

$$\phi = 0.05 \sin 377t \qquad \text{Wb}$$

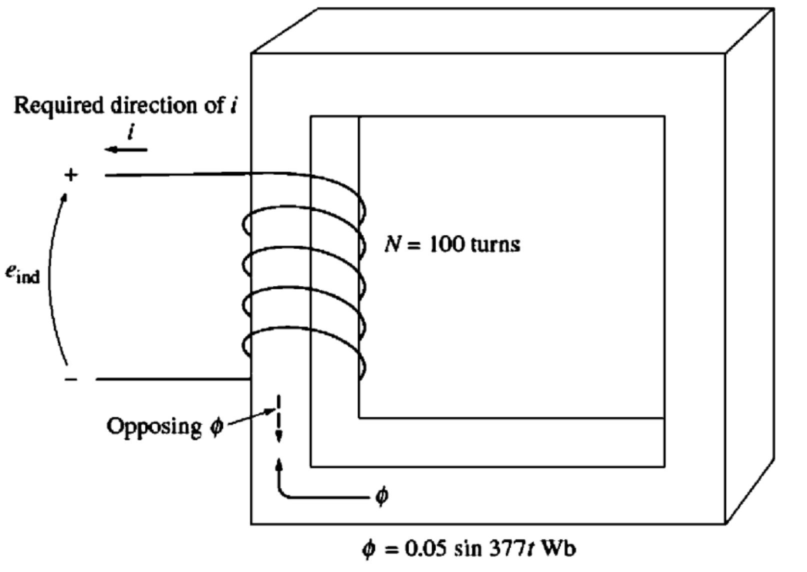
If there are 100 turns on the core, what voltage is produced at the terminals of the coil?

$$e_{ind} = N\frac{d\phi}{dt}$$

$$= (100 \text{ turns})\frac{d}{dt}(0.05 \sin 377t)$$

$$= 1885 \cos 377t$$

$$e_{ind} = 1885 \sin(377t + 90°) \text{ V}$$

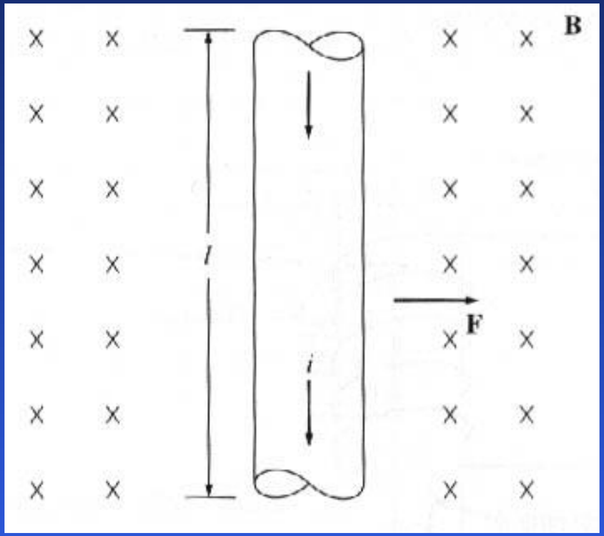


5. Production of induced force on a wire

A second major effect of a magnetic field is that it induces a force on a wire carrying a current within the field.

$$\mathbf{F} = i(\mathbf{l} \times \mathbf{B})$$

Left hand rule (2.32.1)



Where *l* is a vector of current, *B* is the magnetic flux density vector.

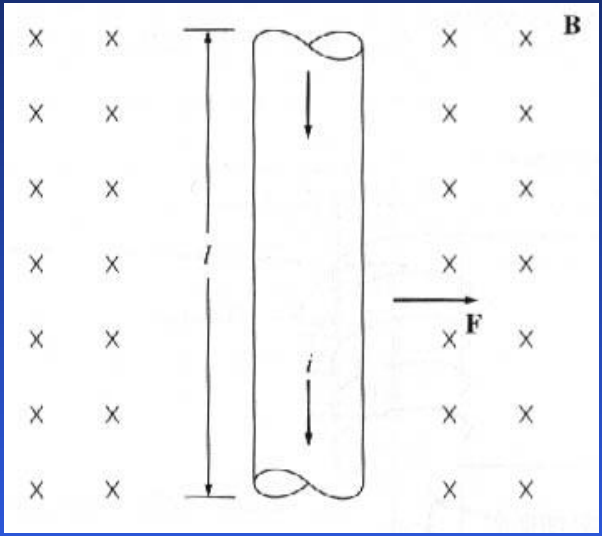
For a wire of length *l* caring a current *i* in a magnetic field with a flux density *B* that makes an angle θ to the wire, the magnitude of the force is:

$$F = ilB\sin\theta \tag{2.32.2}$$

This is a basis for a motor action.

Example: induced force

Figure 1- 16 shows a wire carrying a current in the presence of a magnetic field. The magnetic flux density is 0.25 T. directed into the page. If the wire is 1.0 m long and carries 0.5 A of current in the direction from the top of the page to the bottom of the page. what are the magnitude and direction of the force induced on the wire?.



$$F = ilB \sin \theta$$

$$= (0.5 \text{ A})(1.0 \text{ m})(0.25 \text{ T}) \sin 90° = 0.125 \text{ N}$$

$$\mathbf{F} = 0.125 \text{ N, directed to the right}$$