The Inductor

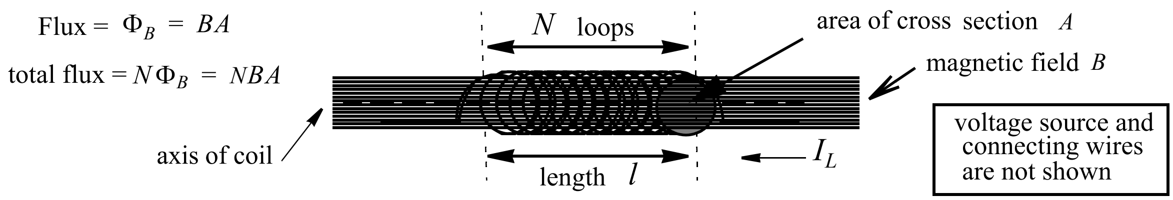
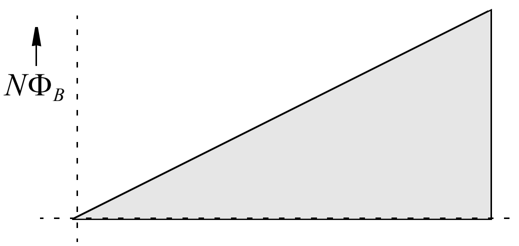


Fig (1) The Geometrical Parameters of the Inductor



$$\text{slope} = \frac{\Delta y}{\Delta x} = \frac{\Delta(N\Phi_B)}{\Delta(I_L)} = \frac{(N\Phi_B)}{I_L} = L = \text{Inductance}$$

$$\text{area} = (1/2)\,(I_L)\,(N\Phi_B) = \text{Energy}$$

Fig (2) Electrical Energy Stored in the Magnetic Field of the Inductor

Table 1: An Inductor in a DC Circuit

#	Property	Mathematical Expression	#	Property	Mathematical Expression
1	Length	l, (m)	8	Magnetic field (Ampere's law)	$B = \dfrac{\mu_o(NI_L)}{l}$, (T)
2	Area of cross-section	A, (m^2)	9	Magnetic flux Total mag. flux	$\Phi_B = BA$, (Tm^2) $N\Phi_B = NBA$, (Tm^2)
3	Volume	$V = Al$, (m^3)	10	Magnetic flux	$N\Phi_B = \left(\dfrac{\mu_o N^2 A}{l}\right) I_L$, (Tm^2)
4	Number of turns	N			
5	Resistance	R_L, (Ω)	11	Inductance (Coefficient of self Inductance)	$L = \dfrac{N\Phi_B}{I_L} = \dfrac{\mu_o N^2 A}{l}$, (H)
6	Ohm's Law	$V_L = R_L I_L$ (V)	12	Energy stored (J)	$U_B = (\frac{1}{2})(I_L)(N\Phi_B) = \dfrac{N\Phi_B{}^2}{2L}$ $= (\frac{1}{2})(LI_L^2) = \left(\dfrac{B^2}{2\mu_o}\right)(Al)$
7	Effective current producing magnetic field	NI_L, (A)	13	Energy density	$u_B = \dfrac{B^2}{2\mu_o}$, (J/m^3)

Inductor in a DC circuit

Electrical Aspect

The inductor is replaced by its *DC* resistance: R_L

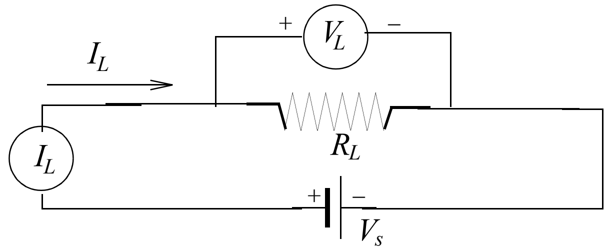


Fig (3) Equivalent Electrical Circuit

(1) Ohm's law is being obeyed: $V_L = R_L I_L$

(2) Electrical energy is being dissipated at the rate: $P_L = (I_L^2)R_L$

Magnetic Aspect

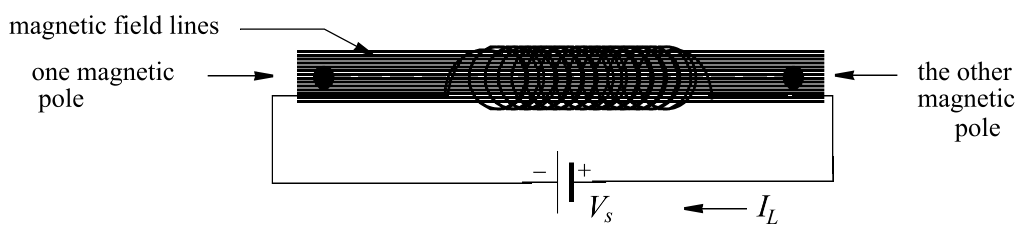


Fig (4 Magnetic Field Produced by a Coil

(1) Magnetic field ***B*** is being produced: $B = \{\mu_o(NI_L)\}/(l)$

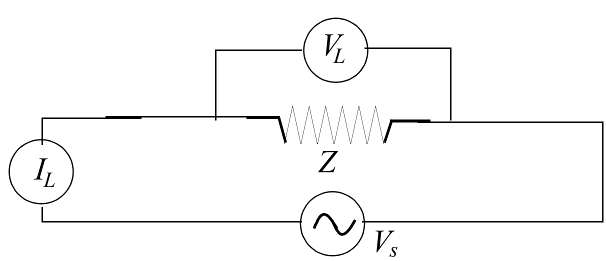
(2) A steady magnetic flux $N\Phi_B$, is being generated in the coil

(2) Electrical energy is being stored as magnetic energy, $U_B = (\frac{1}{2})(I_L)(N\Phi_B)$.

Inductor in an AC circuit

Electrical Aspect

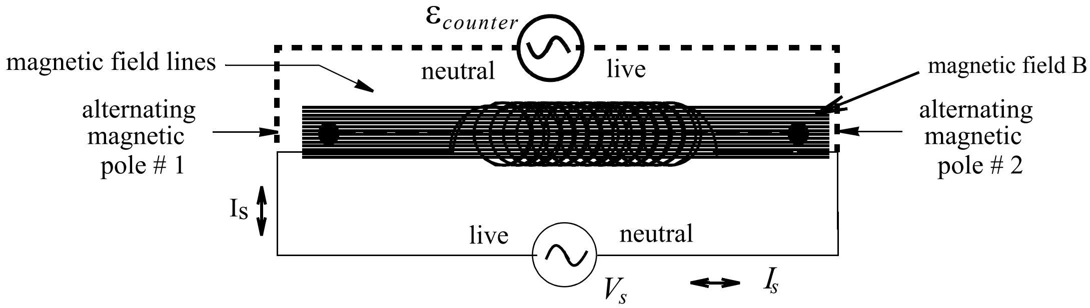
The inductor is replaced by its impedance *Z*. All voltages and currents have *rms* values.



(1) Ohm's law is being obeyed. $V_L = Z(I_L^{-})$

(2) Electrical energy is being dissipated in the *DC* resistance R_L at the rate: $P_L = (I_L^2)R_L$

Magnetic Aspect



(1) Magnetic field $\boldsymbol{B}$ is being produced. The polarity of $\boldsymbol{B}$ keeps switching between *north* and *south* poles because of the sinusoidal nature of voltages and currents.

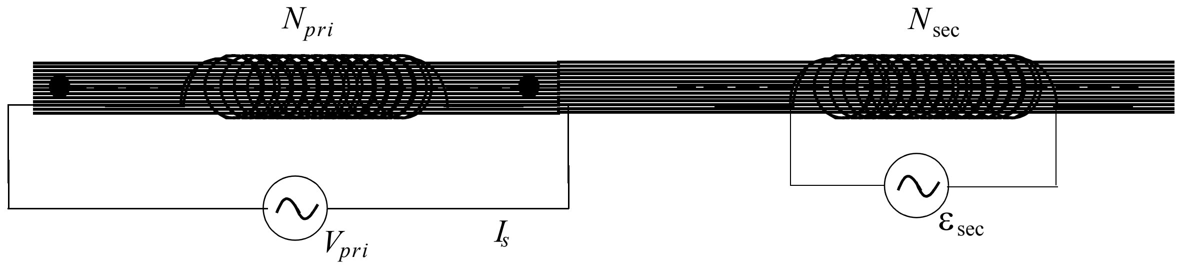
(2) A changing magnetic flux $N\Phi_B$, is being generated in the coil. It is changing sinusoidally. It extends *axially* beyond the coil on both sides.

(3) The time rate of change of magnetic flux: $\{\Delta(N\Phi_B)\}/(\Delta t)$ is equivalent to an emf ε which has a polarity opposite to that of the applied source voltage V_s. We call it *counter emf,* $\varepsilon_{counter}$, and hence write it with a negative sign.

$$\varepsilon_{counter} = \varepsilon_L = -\frac{\Delta(N\Phi_B)}{\Delta t}$$

Doing More

The extended *changing magnetic flux* is made to induce emf in a foreign, totally isolated, nearby coil, thereby giving rise to gadgets of the family known as *Transformers,* starring Megan Fox. The popularity is beyond words.



Magnitude of the induced emf is given by:

$$\varepsilon_{\sec} = \left(\frac{N_{\sec}}{N_{pri}}\right)(V_{pri})$$

The ratio of the number of turns of the primary and the secondary coils $N_{\sec}/N_{pri}$ should better be called the *fox factor.* It has no units. It is easy to see that:

$$\text{fox factor} = \frac{N_{\sec}}{N_{pri}} = \frac{\varepsilon_{\sec}}{V_{pri}} = \frac{I_{pri}}{I_{\sec}} = \frac{M}{L_{pri}}$$

The End