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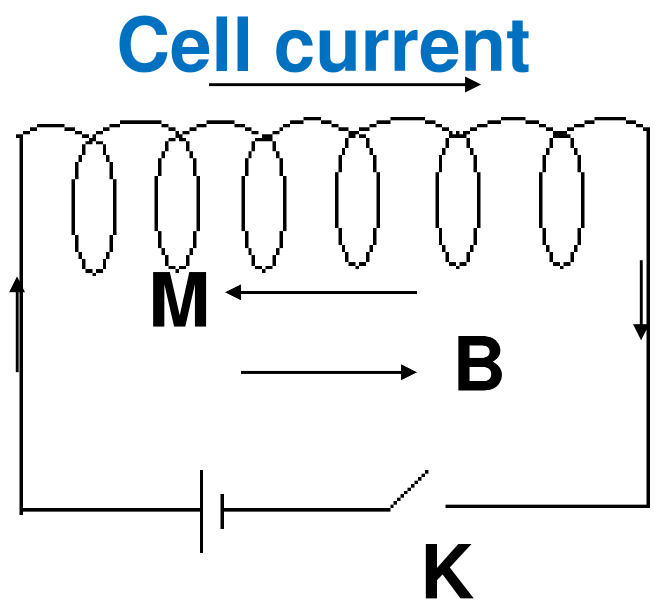
Self Induction

Self induction is the property of a coil by the virtue of which it opposes any change in the strength of current flowing through it by inducing an e.m.f. in itself. For this reason self-inductance is also called the inertia of electricity.



On pressing key K current through the cell increases from zero to a certain maximum value which takes some time. During this time (Make time M) current through the coil is increasing , magnetic flux linked with the coil is increasing, therefore, a current is induced in the coil. So according to Lenz's law, the induced current at the make will oppose the growth of current in the coil by flowing in the direction opposite to the direction of the cell current.

Similarly, on releasing the key, current through the coil decreases so during this time (Break time B) current through the coil is decreasing and magnetic flux linked with the coil is also decreasing. A current is induced in the coil, which is according to Lenz's law will oppose the decay of current in the coil by flowing in the direction of cell current, so as to prolong it.

Co-efficient of Self-inductance

I = strength of current flowing through a coil at any time.

Φ = amount of magnetic flux linked with all the turns of the coil at that time

$\Phi \propto I$

$\Phi = LI$; where L = Coefficient of self-induction

Its value depends upon the number of turns of the coil, area of cross-section, and the nature of the material of the core on which the coil is wound.

If $I = 1$, $\Phi = L \times 1 = L$

Therefore, the coefficient of self-induction of a coil is numerically equal to the amount of magnetic flux linked with the coil when unit current flows through the coil.

e.m.f. induced in the coil is given by,

$e = -d\Phi/dt = -d/dt\,(LI)$

$$e = -L\,dI/dt$$

If $dI/dt = 1$, then, $e = -L \times 1 = -L$

Hence, the coefficient of self-induction of a coil is equal to the e.m.f. induced in the coil when the rate of change of current through the coil is unity.

The S.I. unit of L is Henry.

Self inductance of a coil is said to be one Henry when a current changes at a rate of 1 ampere/second through the coil induces an e.m.f. of 1Volt in the coil.

A wire cannot act as an inductor as the magnetic flux linked with the wire of negligible area of cross-section is zero. The wire has to be in the form of a coil to serve as an inductor and also self induced e.m.f. appears only during the time the current is changing.

Numerical Problem

Q: What e.m.f. will be induced in a 10 H inductor in which current changes from 10A to 7A in 9×10^{-2} s ?

Solution: $L = 10H$, $I_1 = 10A$, $I_2 = 7A$, $dt = 9 \times 10^{-2} s$

As $e = -L\, dI/dt$,

$= -L\,(I_2 - I_1)/dt$

$= -10\,(7-10)/\, 9 \times 10^{-2}$

$= 333.3$ Volt

Self-inductance of a long solenoid

A long solenoid is that whose length is very large as compared to its radius. The magnetic field B at any point inside a solenoid is practically constant and is given by,

$B = \mu_0 NI/\ell$

Where μ_0 is absolute magnetic permeability of free space which forms the core of the solenoid, ℓ is the length, N is the number of turns in the solenoid.

Total magnetic flux linked with the solenoid = flux through each turn x total number of turns

$\Phi = \mu_0 NI/\ell \times A \times N$

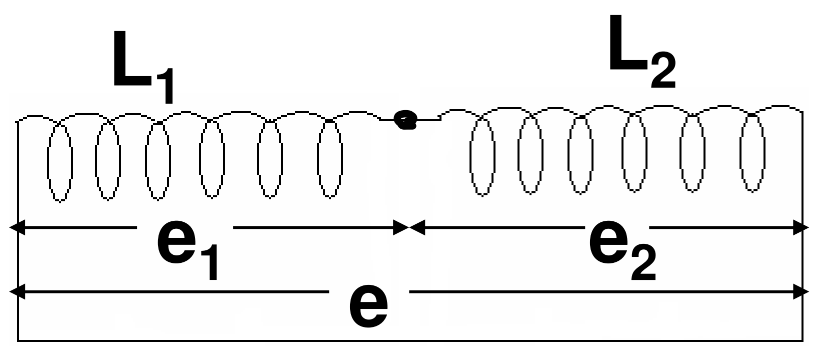
$\Phi = LI$

$L = \mu_0 AN^2/\ell$

Grouping of coils

IN SERIES: When two coils of inductance L_1 and L_2 are connected in series and the coefficient of coupling K is equal to zero then current through each coil is same and potential divides, therefore,

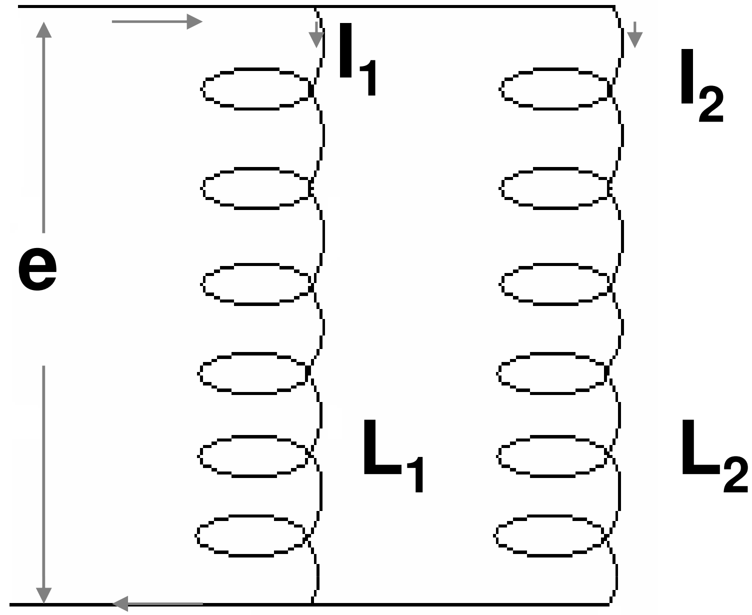
$e = e_1 + e_2$



$L_s \, dI/dt = L_1 \, dI/dt + L_2 \, dI/dt$

$$\boxed{L_s = L_1 + L_2}$$

IN PARALLEL :



$I = I_1 + I_2$

$dI/dt = dI_1/dt + dI_2/dt$

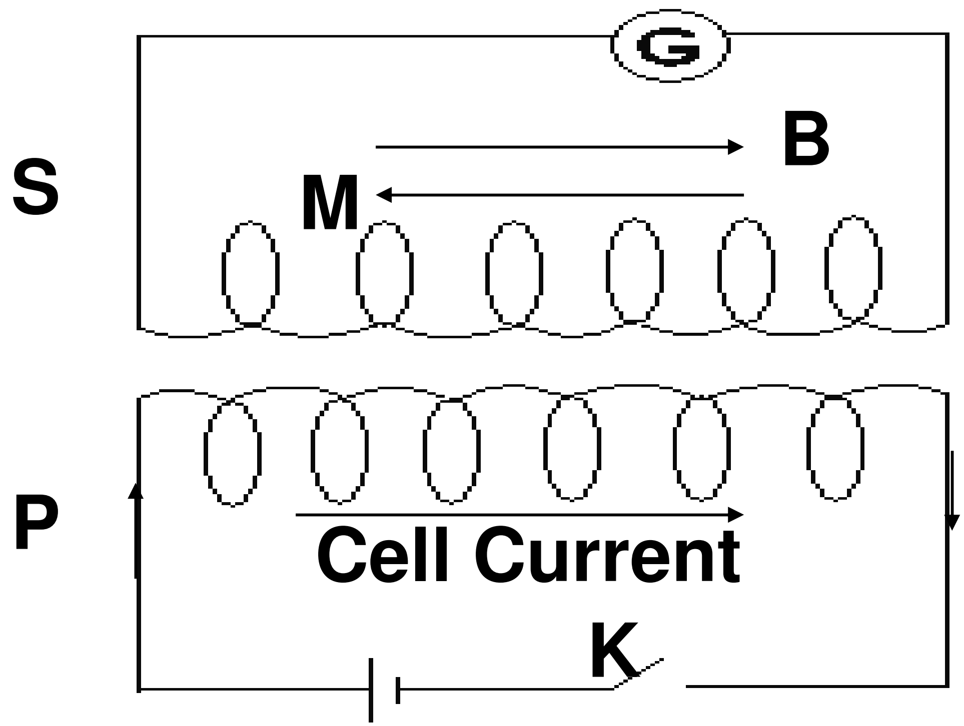
$e/L = e_1/L_1 + e_2/L_2$

As $e_1 = e_2 = e$, therefore,

$1/L = 1/L_1 + 1/L_2$)

Mutual Induction

Mutual induction is the property of two coils by virtue of which each opposes any change in the strength of current flowing through the other by developing an induced e.m.f.



On pressing K, current in P increases from zero to maximum value. It takes some time (Make time M) current is increasing in P, magnetic flux linked with P is also increasing. As S is closeby, magnetic flux associated with S also increases, an e.m.f. is induced in S. So, according to Lenz’s law, induced current in S would oppose increase in current in P by flowing in direction opposite to the cell current in P.

Similarly, on releasing K, current in P decreases from maximum to zero value during Break time magnetic flux linked with P is decreasing and also in S. e.m.f. is induced in S.

So according to Lenz's law, induced current in S flows in the direction of cell current in P so as to oppose the decrease in current in P.

Co-efficient of Mutual inductance

I = strength of current flowing in one coil

Φ = amount of magnetic flux linked with the neighbouring coil

$\Phi \propto I$

$\Phi = MI$; where M = Coefficient of mutual induction

If $I = 1$, $\Phi = M \times 1 = M$

Therefore, the coefficient of mutual induction of two coils is numerically equal to the amount of magnetic flux linked with one coil when unit current flows through the e.m.f. induced in the coil is given by,

$e = -d\Phi/dt = -d/dt\ (MI)$

$e = -M\ dI/dt$

If $dI/dt = 1$, then, $e = -M \times 1 = -M$

Hence, the coefficient of mutual induction of two coils is equal to the e.m.f. induced in one coil when the rate of change of current through the other coil is unity.

The S.I. unit of M is Henry.

Mutual inductance of two coils is said to be one Henry when a current changes at a rate of 1 ampere/second in one coil induces an e.m.f. of 1Volt in the other coil.

Mutual Inductance of two long solenoids

S_1 solenoid air core has N_1 turns and another solenoid S_2 has N_2 turns is wound over the solenoid. ℓ is equal to the length of each solenoid. Magnetic field B_1 at any point inside S_1 due to a current I_1 is,

$B_1 = \mu_0 N_1 I_1 / \ell$

Total magnetic flux linked with solenoid S_2,

$\Phi_2 = B_1 x A x N_2$

$= (\mu_0 N_1 I_1/\ell) A x N_2$

But, magnetic flux Φ_2 linked with S_2 due to current I_1 through S_1.

So, $\Phi_2 \alpha I_1$

$\Phi_2 = M I_1$

$M = (\mu_0 N_1/\ell) A x N_2$

Numerical Problem

Q: What is the mutual inductance of a pair of coils if a current change of 6 A in one coil causes the flux in the second coil of 2000 turns to change by 12×10^{-4} Wb per turn ?

Solution: I = 6A, N = 2000

$\Phi = MI$

$M = \Phi / I$; $\Phi = 2000 \times 12 \times 10^{-4} = 2.4$ Wb

$= 2.4/6 = 0.4$ H