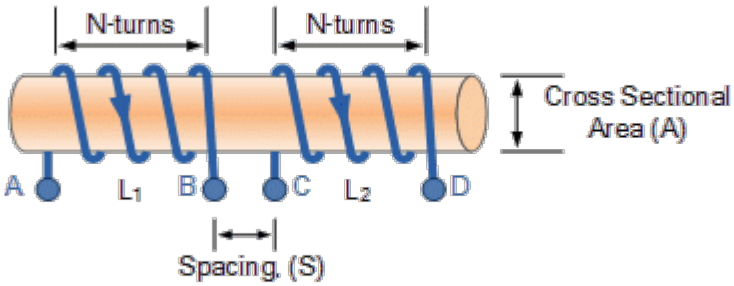


Mutual Inductance

Mutual Inductance is the interaction of one coils magnetic field on another coil as it induces a voltage in the adjacent coil

In the previous tutorial we saw that an inductor generates an induced emf within itself as a result of the changing magnetic field around its own turns. When this emf is induced in the same circuit in which the current is changing this effect is called **Self-induction**, (L).

However, when the emf is induced into an adjacent coil situated within the same magnetic field, the emf is said to be induced magnetically, inductively or by **Mutual induction**, symbol (M). Then when two or more coils are magnetically linked together by a common magnetic flux they are said to have the property of **Mutual Inductance**.

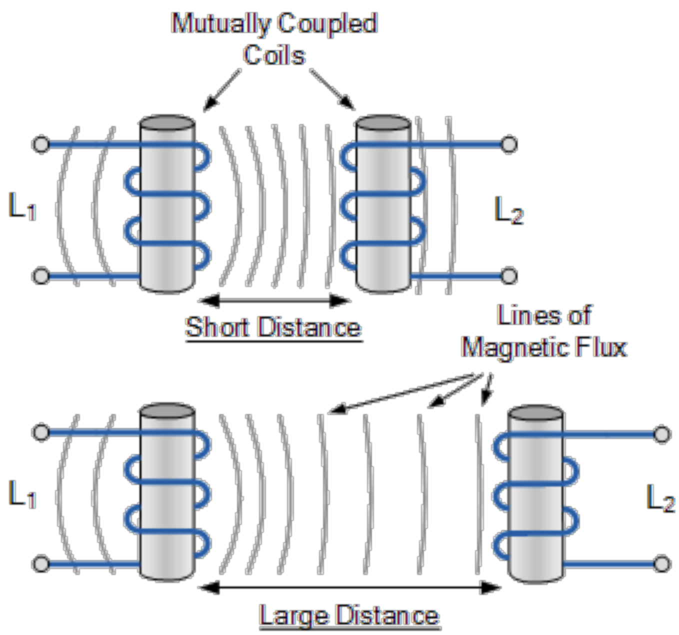
Mutual Inductance is the basic operating principal of the transformer, motors, generators and any other electrical component that interacts with another magnetic field. Then we can define mutual induction as the current flowing in one coil that induces a voltage in an adjacent coil.

But mutual inductance can also be a bad thing as “stray” or “leakage” inductance from a coil can interfere with the operation of another adjacent component by means of electromagnetic induction, so some form of electrical screening to a ground potential may be required.

The amount of mutual inductance that links one coil to another depends very much on the relative positioning of the two coils. If one coil is positioned next to the other coil so that their physical distance apart is small, then nearly all of the magnetic flux generated by the first coil will interact with the coil turns of the second coil inducing a relatively large emf and therefore producing a large mutual inductance value.

Likewise, if the two coils are farther apart from each other or at different angles, the amount of induced magnetic flux from the first coil into the second will be weaker producing a much smaller induced emf and therefore a much smaller mutual inductance value. So the effect of mutual inductance is very much dependant upon the relative positions or spacing, (S) of the two coils and this is demonstrated below.

Mutual Inductance between Coils



The mutual inductance that exists between the two coils can be greatly increased by positioning them on a common soft iron core or by increasing the number of turns of either coil as would be found in a transformer.

If the two coils are tightly wound one on top of the other over a common soft iron core unity coupling is said to exist between them as any losses due to the leakage of flux will be extremely small. Then assuming a perfect flux linkage between the two coils the mutual inductance that exists between them can be given as.

$$M = \frac{\mu_o \mu_r N_1 N_2 A}{\ell}$$

Where:

μ_o is the permeability of free space ($4.\pi.10^{-7}$)

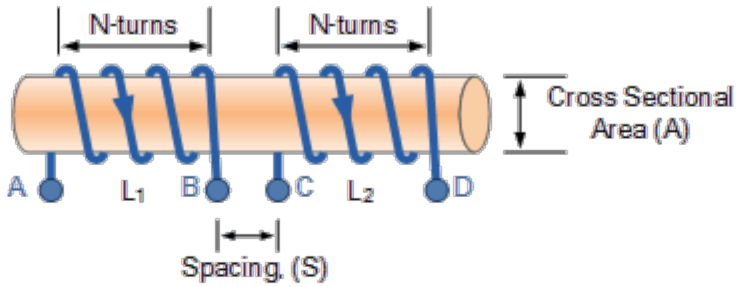
μ_r is the relative permeability of the soft iron core

N is in the number of coil turns

A is in the cross-sectional area in m^2

ℓ is the coils length in meters

Mutual Induction



Here the current flowing in coil one, L_1 sets up a magnetic field around itself with some of these magnetic field lines passing through coil two, L_2 giving us mutual inductance. Coil one has a current of I_1 and N_1 turns while, coil two has N_2 turns. Therefore, the mutual inductance, M_{12} of coil two that exists with respect to coil one depends on their position with respect to each other and is given as:

$$M_{12} = \frac{N_2 \Phi_{12}}{I_1}$$

Likewise, the flux linking coil one, L_1 when a current flows around coil two, L_2 is exactly the same as the flux linking coil two when the same current flows around coil one above, then the mutual inductance of coil one with respect of coil two is defined as M_{21}. This mutual inductance is true irrespective of the size, number of turns, relative position or orientation of the two coils. Because of this, we can write the mutual inductance between the two coils as: $M_{12} = M_{21} = M$.

Then we can see that self inductance characterises an inductor as a single circuit element, while mutual inductance signifies some form of magnetic coupling between two inductors or coils, depending on their distance and arrangement, an hopefully we remember from our tutorials on **Electromagnets** that the self inductance of each individual coil is given as:

$$L_1 = \frac{\mu_o \mu_r N_1^2 A}{\ell} \quad \text{and} \quad L_2 = \frac{\mu_o \mu_r N_2^2 A}{\ell}$$

By cross-multiplying the two equations above, the mutual inductance, M that exists between the two coils can be expressed in terms of the self inductance of each coil.

$$M^2 = L_1 L_2$$

giving us a final and more common expression for the mutual inductance between the two coils of:

Mutual Inductance Between Coils

$$\boxed{M = \sqrt{L_1 L_2} \ \ H}$$

However, the above equation assumes zero flux leakage and 100% magnetic coupling between the two coils, L_1 and L_2. In reality there will always be some loss due to leakage and position, so the magnetic coupling between the two coils can never reach or exceed 100%, but can become very close to this value in some special inductive coils.

If some of the total magnetic flux links with the two coils, this amount of flux linkage can be defined as a fraction of the total possible flux linkage between the coils. This fractional value is called the **coefficient of coupling** and is given the letter k.

Coupling Coefficient

Generally, the amount of inductive coupling that exists between the two coils is expressed as a fractional number between 0 and 1 instead of a percentage (%) value, where 0 indicates zero or no inductive coupling, and 1 indicating full or maximum inductive coupling.

In other words, if $k = 1$ the two coils are perfectly coupled, if $k > 0.5$ the two coils are said to be tightly coupled and if $k < 0.5$ the two coils are said to be loosely coupled. Then the equation above which assumes a perfect coupling can be modified to take into account this coefficient of coupling, k and is given as:

Coupling Factor Between Coils

$$k = \frac{M}{\sqrt{L_1 L_2}} \quad \text{or} \quad M = k\sqrt{L_1 L_2}$$

When the coefficient of coupling, k is equal to 1, (unity) such that all the lines of flux of one coil cuts all of the turns of the second coil, that is the two coils are tightly coupled together, the resulting mutual inductance will be equal to the geometric mean of the two individual inductances of the coils.

Also when the inductances of the two coils are the same and equal, L_1 is equal to L_2, the mutual inductance that exists between the two coils will equal the value of one single coil as the square root of two equal values is the same as one single value as shown.

$$M = \sqrt{L_1 L_2} = L$$

Mutual Inductance Example No1

Two inductors whose self-inductances are given as 75mH and 55mH respectively, are positioned next to each other on a common magnetic core so that 75% of the lines of flux from the first coil are cutting the second coil. Calculate the total mutual inductance that exists between the two coils.

$$M = k\sqrt{L_1 L_2}$$

$$M = 0.75\sqrt{75\text{mH} \times 55\text{mH}} = 48.2\text{mH}$$

Mutual Inductance Example No2

When two coils having inductances of 5H and 4H respectively were wound uniformly onto a non-magnetic core, it was found that their mutual inductance was 1.5H. Calculate the coupling coefficient that exists between.

$$k = \frac{M}{\sqrt{L_1 L_2}} = \frac{1.5}{\sqrt{5 \times 4}} = 0.335 = 33.5\%$$

In the next tutorial about Inductors, we look at connecting together Inductors in Series and the affect this combination has on the circuits mutual inductance, total inductance and their induced voltages.

141 Comments

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Your Name

Email Address

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Notify me of follow-up comments by email.

SUBMIT

S. Anitha

Super

Posted on December 01st 2020 | 3:23 am

Reply

Abdi

I need a note

Posted on October 19th 2020 | 3:10 pm

Reply

---

ulhas patil dyandev

Hii sir rewinding core same turn but mh value decress so please tell me how to increase mh

Posted on August 16th 2020 | 2:29 am

Reply

Divyayan

How can we express mutual inductance as a function of the coil separation distance between two adjacent resonators?

Posted on June 16th 2020 | 5:33 am

Reply

Ruth

I think it's great

Posted on May 09th 2020 | 5:32 pm

Reply

V R Gojiya

I want to know in which condition the mutual induction comes out to be negative?

Posted on April 24th 2020 | 5:16 am

Reply

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himani bharambe

Best information

Posted on March 27th 2020 | 3:24 pm

Reply

Adharsh

When did we put negative sign while doing problems on mutual induction,emf questions

Posted on March 25th 2020 | 4:02 pm

Reply

Harshal Vide

Distance between 2 coil of 40uH is. 10 cm then what is the mutual induction

Posted on March 11th 2020 | 5:06 pm

Reply

Harshal Vide

Thank you very much ,it’s very useful for my project which is wireless power transmission

Posted on March 11th 2020 | 5:03 pm

Reply

Kelvin

Please forward to me work examples of mutual inductance BTW coil

Posted on March 06th 2020 | 6:16 am

Reply

Tanya-ta singh

How to first kick on mutual induction experiment?

Posted on February 29th 2020 | 3:33 am

Reply

Dr.Ahmed Bakry

what is difference between magnetic flux 12 and 21?

Posted on February 27th 2020 | 6:26 am

Reply

Wayne Storr

12 relates to the magnetic flux through coil 2 due to coil 1.
21 relates to the magnetic flux through coil 1 due to coil 2.
Thus, the changing magnetic flux in one coil produces a changing magnetic flux in the other coil

Posted on February 27th 2020 | 8:20 am

Reply

Ankita

Thank you

Posted on February 25th 2020 | 6:12 pm

Reply

Peter Dut Atueny

how to calculate mutual inductance of two coils and current

Posted on February 22nd 2020 | 8:59 pm

Reply

William Akol Madut Riiny

I need to join group of engineers

Posted on February 21st 2020 | 2:57 am

Reply

SUDHAKAR PATRA

i want to learn, How I am calculate transformar turn

Posted on February 13th 2020 | 3:43 pm

Reply

DJ

What will be the mutual inductance when same situation but a current direction of one of the coils changes to opposite? (means the direction of two fluxes generated by currents on the two different coils are opposite)

Is the equation same or change?

Posted on January 23rd 2020 | 2:01 am

Reply

Tim Iben

Inductance and Mutual inductance are positive numbers. They define the coupling. The current direction determines the EMF from 1 in two. EMF2=-L2*dI2/dt-M12*dI1dt & EMF1=-L1*dI1/dt-M21*dI2dt

Posted on December 08th 2020 | 3:03 am

Reply

M.Sc. Pedro O. Díaz F.

Thanks for your text, I am studying mutual influence between a coil with ferromagnetic core and another with air core, ¿ M12 = M21?… it is interesting one… please… you can write me the answer?…. Pedro

Posted on December 19th 2019 | 9:39 pm

Reply

Ibrahim chiwar

it's very interested

Posted on November 10th 2019 | 9:18 pm

Reply

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