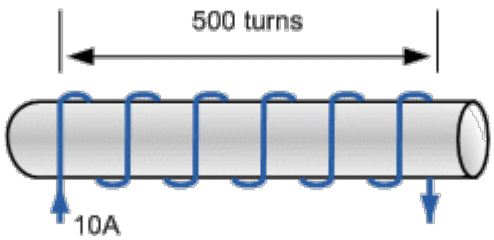


Inductance of a Coil

Inductance is the name given to the property of a component that opposes the change of current flowing through it and even a straight piece of wire will have some inductance

Inductors do this by generating a self-induced emf within itself as a result of their changing magnetic field. In an electrical circuit, when the emf is induced in the same circuit in which the current is changing this effect is called **Self-induction**, (L) but it is sometimes commonly called back-emf as its polarity is in the opposite direction to the applied voltage.

When the emf is induced into an adjacent component situated within the same magnetic field, the emf is said to be induced by **Mutual-induction**, (M) and mutual induction is the basic operating principal of transformers, motors, relays etc. Self inductance is a special case of mutual inductance, and because it is produced within a single isolated circuit we generally call self-inductance simply, **Inductance**.

The basic unit of measurement for inductance is called the **Henry**, (H) after Joseph Henry, but it also has the units of **Webers per Ampere** (1 H = 1 Wb/A).

Lenz's Law tells us that an induced emf generates a current in a direction which opposes the change in flux which caused the emf in the first place, the principal of action and reaction. Then we can accurately define **Inductance** as being: "a coil will have an inductance value of one Henry when an emf of one volt is induced in the coil were the current flowing through the said coil changes at a rate of one ampere/second".

In other words, a coil has an inductance, (L) of one Henry, (1H) when the current flowing through the coil changes at a rate of one ampere/second, (A/s). This change induces a voltage of one volt, (V_L) in it. Thus the mathematical representation of the rate of change of current through a wound coil per unit time is given as:

$$\frac{di}{dt} \quad (A/s)$$

Where: *di* is the change in the current in Amperes and *dt* is the time taken for this current to change in seconds. Then the voltage induced in a coil, (V_L) with an inductance of L Henries as a result of this change in current is expressed as:

$$V_L = -L\frac{di}{dt} \quad (V)$$

Note that the negative sign indicates that voltage induced opposes the change in current through the coil per unit time (di/dt).

From the above equation, the inductance of a coil can therefore be presented as:

Inductance of a Coil

$$L = \frac{V_L}{(di/dt)} = \frac{1\text{volt}}{1A/s} = 1\text{Henry}$$

Where: L is the inductance in Henries, V_L is the voltage across the coil and di/dt is the rate of change of current in Amperes per second, A/s.

Inductance, L is actually a measure of an inductors "resistance" to the change of the current flowing through the circuit and the larger is its value in Henries, the lower will be the rate of current change.

We know from the previous tutorial about the Inductor, that inductors are devices that can store their energy in the form of a magnetic field. Inductors are made from individual loops of wire combined to produce a coil and if the number of loops within the coil are increased, then for the same amount of current flowing through the coil, the magnetic flux will also increase.

So by increasing the number of loops or turns within a coil, increases the coils inductance. Then the relationship between self-inductance, (L) and the number of turns, (N) and for a simple single layered coil can be given as:

Self Inductance of a Coil

$$L = N\frac{\Phi}{I}$$

Where:

L is in Henries

N is the Number of Turns

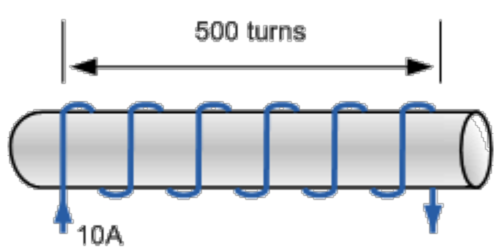
Φ is the Magnetic Flux

I is in Amperes

This expression can also be defined as the magnetic flux linkage, ($N\Phi$) divided by the current, as effectively the same value of current flows through each turn of the coil. Note that this equation only applies to linear magnetic materials.

Inductance Example No1

A hollow air cored inductor coil consists of 500 turns of copper wire which produces a magnetic flux of 10mWb when passing a DC current of 10 amps. Calculate the self-inductance of the coil in milli-Henries.



$$L = N\frac{\Phi}{I} = 500\frac{0.01}{10} = 500\text{mH}$$

Inductance Example No2

Calculate the value of the self-induced emf produced in the same coil after a time of 10mS.

$$\text{emf} = L\frac{di}{dt} = 0.5\frac{10}{0.01} = 500V$$

The self-inductance of a coil or to be more precise, the coefficient of self-inductance also depends upon the characteristics of its construction. For example, size, length, number of turns etc. It is therefore possible to have inductors with very high coefficients of self induction by using cores of a high permeability and a large number of coil turns. Then for a coil, the magnetic flux that is produced in its inner core is equal to:

$$\Phi = B.A$$

Where: Φ is the magnetic flux, B is the flux density, and A is the area.

If the inner core of a long solenoid coil with N number of turns per metre length is hollow, “air cored”, then the magnetic induction within its core will be given as:

$$B = \mu_o H = \mu_o \frac{N.I}{\ell}$$

Then by substituting these expressions in the first equation above for Inductance will give us:

$$L = N\frac{\Phi}{I} = N\frac{B.A}{I} = N\frac{\mu_o.N.I}{\ell.I}.A$$

By cancelling out and grouping together like terms, then the final equation for the coefficient of self-inductance for an air cored coil (solenoid) is given as:

$$\boxed{L = \mu_o \frac{N^2.A}{\ell}}$$

Where:

L is in Henries

μ_o is the Permeability of Free Space ($4.\pi.10^{-7}$)

N is the Number of turns

A is the Inner Core Area (πr^2) in m^2

ℓ is the length of the Coil in metres

As the inductance of a coil is due to the magnetic flux around it, the stronger the magnetic flux for a given value of current the greater will be the inductance. So a coil of many turns will have a higher inductance value than one of only a few turns and therefore, the equation above will give inductance L as being proportional to the number of turns squared N^2.

EEWeb have a free online **Coil Inductance Calculator** for calculating the inductance of a coil for different configurations of wire size and positioning.

As well as increasing the number of coil turns, we can also increase inductance by increasing the coils diameter or making the core longer. In both cases more wire is required to construct the coil and therefore, more lines of force exists to produce the required back emf.

The inductance of a coil can be increased further still if the coil is wound onto a ferromagnetic core, that is one made of a soft iron material, than one wound onto a non-ferromagnetic or hollow air core.

If the inner core is made of some ferromagnetic material such as soft iron, cobalt or nickel, the inductance of the coil would greatly increase because for the same amount of current flow the magnetic flux generated would be much stronger. This is because the material concentrates the lines of force more strongly through the the softer ferromagnetic core material as we saw in the Electromagnets tutorial.

Ferrite Core

So for example, if the core material has a relative permeability 1000 times greater than free space, $1000\mu_o$ such as soft iron or steel, then the inductance of the coil would be 1000 times greater so we can say that the inductance of a coil increases proportionally as the permeability of the core increases.

Then for a coil wound around a former or core the inductance equation above would need to be modified to include the relative permeability μ_r of the new former material.

If the coil is wound onto a ferromagnetic core a greater inductance will result as the cores permeability will change with the flux density. However, depending upon the type of ferromagnetic material, the inner cores magnetic flux may quickly reach saturation producing a non-linear inductance value. Since the flux density around a coil of wire depends upon the current flowing through it, inductance, L also becomes a function of this current flow, i.

In the next tutorial about inductors, we will see that the magnetic field generated by a coil can cause a current to flow in a second coil that is placed next to it. This effect is called Mutual Inductance, and is the basic operating principle of transformers, motors and generators.

138 Comments

Join the conversation

Your Name

Email Address

Write your comment here

Notify me of follow-up comments by email.

SUBMIT

Myint Myint Aye

I like your teaching.

Posted on November 29th 2020 | 6:35 am

Reply

P

PRINCEPEE ADENIYI

I need more lights on this

Posted on November 10th 2020 | 10:26 am

Reply

N

Narendra Singh

S. S. Coil

Posted on November 03rd 2020 | 6:38 pm

Reply

M

Mensah

That's a very good tutorial. I like it.
Thumps up.

Posted on August 19th 2020 | 6:52 am

Reply

A

ahmad

100uh 20a

Posted on August 08th 2020 | 7:27 am

Reply

M

Mgeta

What is different between self and mutual inductance

Posted on August 08th 2020 | 9:49 am

Reply

M

Masawa

Nice explanation about the self inductance

Posted on August 06th 2020 | 9:51 am

Reply

A

Adebola Tawose

The voltage induced across a 25 u H coil when the rate of change of the current is 10,000 A/s is

Posted on July 17th 2020 | 11:32 am

Reply

W

Wayne Storr

0.25V

Posted on July 17th 2020 | 3:52 pm

Reply

J

JMMC

A current of 10 amp produces a total flux of 10 webers in a closely wound coil of 200 turns. Find the energy stored in the magnetic field.

Posted on July 13th 2020 | 7:29 am

Reply

M

Mercy

The tutorial was helpful

Posted on May 03rd 2020 | 4:14 pm

Reply

D

Darshan lal anand

Good simple way to offer learning experience thanks

Posted on April 27th 2020 | 5:57 am

Reply

S

Shankar Shinde

Really nice and helpful tutorial.

Posted on April 25th 2020 | 12:24 pm

Reply

C

Chetan anam

How do you find out the thickness of the wire to be used? Is the final value of the inductance independent of wire thickness or we select the wire thickness by the amount of maximum current that is expected to flow through the inductance? If the coil length is less than the core length, what does the small l represent?

Posted on January 27th 2020 | 12:59 pm

Reply

L

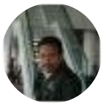
Lahcene Akrour

Hello sur,

I notice that in this tutorial you set the formula of the emf as V=L.di/dt. But in a previous tutoral, N°2, "Inductance of a coil" you set it as $V = -L.di/dt$ that is adding a minus sign to the formula. Please tell me when you may use one or the other formula.

Posted on December 14th 2019 | 9:14 am

Reply



Wijono

This formula gives a far different from the real inductance of coils. Many times I try, the calculation gives us hundred times higher than the actual measured values.

Posted on September 27th 2019 | 12:28 am

Reply

Daniel chand

helo

Posted on September 03rd 2019 | 11:50 pm

Reply

Sachin dave

I want to know the calculations of ferrite core CT winding.. How to select the core and turns..? Suppose my input in ferrite core CT is 100 amp and output is 10 mili amp then what will be my core size and how may turns I need to take of Which swag.. Plz suggest ne

Posted on August 29th 2019 | 6:45 am

Reply

Miracle

Thanks for this stuff

Posted on August 27th 2019 | 9:39 am

Reply

---

rowan mamdouh

what is the solution of this problem :at certain moment le the electric current passing theough a coil of résistance 0.4 ohm and inductive coefficient 0.2 Henry is 0.3 A.and increased in the rate of 0.5A/s , calculate the potentiel diffefence through te coil et that moment

Posted on May 01st 2019 | 1:52 pm

Reply

More

Kapila

Do sharp bends create inductance?
I have heard more voltages create with sharp bends when surges flow.

Posted on February 28th 2019 | 5:19 am

Reply

Bhanupratap

Self inductance

Posted on February 21st 2019 | 3:29 pm

Reply

View More