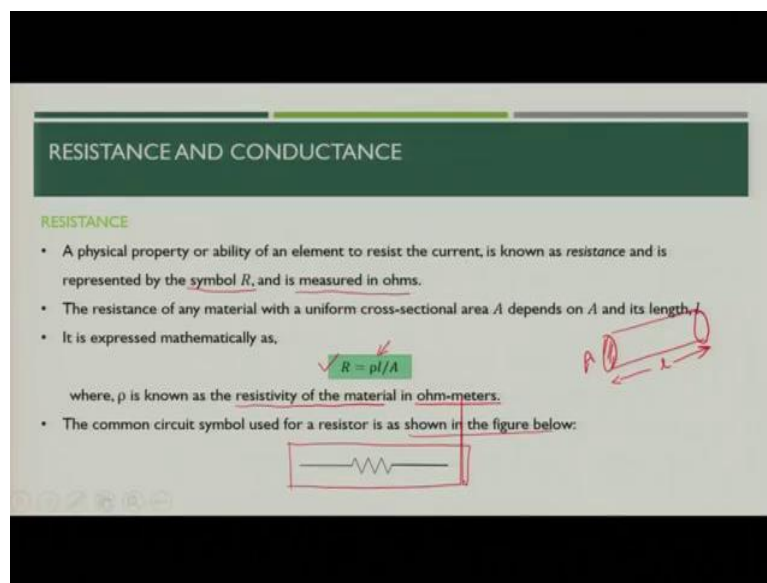


Basic Electric Circuits
Module 01
Basic Circuit Elements and Waveforms
Lecture-03
Circuit Elements Part-1
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Namaskar, so today we will discuss about the various circuit elements in this lecture. Basically, the major passive elements in our electrical circuits are resistor, capacitor, and inductor. So, today we will discuss the various properties of resistors, capacitors, and inductors. Let us start with the first element called resistor. So, let see what see what is resistance? Resistance is a physical property or ability of an element to resist the current. So, basically whenever the current flows in a particular element it tries to oppose the flow of current. So, that property of the element is called resistance.

Now, how you will represent this resistance? The symbol is R . So, generally you will see that in the literature, the symbol R is most commonly used for the resistance and it is measured in ohms. Resistance of any material is dependent on the area as well as length of the element. So, basically if you see cross section of a particular element of area A and length l , the resistance of that particular element is given by $R = \rho l / A$. It means ρ would be the resistivity of the material which is represented in ohm meters, the length of the element, and cross-sectional area

of that element. So, these two are the properties of that element which together with the resistivity of the material will define what is the value of resistances of that element. So, in common circuit elements, resistance is one of the most common and you will see that in the various literature and books, you will see this kind of figure represented for the resistance.

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The slide is titled "RESISTANCE (CONT...)" in green. It contains the following bullet points and equations:

- Georg Simon Ohm (1787–1854), a German physicist, developed the relationship between current and voltage for a resistor.
- This relationship is known as Ohm's law.
- Ohm's law states that the voltage v across a resistor is directly proportional to the current i flowing through the resistor. $\rightarrow v \propto i$
- Ohm defined the constant of proportionality for a resistor to be the resistance, R . $\rightarrow v = R \cdot i$
- From the above equation, $v = iR$

At the bottom, there is a green box containing the equation $R = \frac{v}{i}$ and an arrow pointing to the definition $1\Omega = 1 \frac{V}{A}$.

How did the resistance property come into the literature? George Simon Ohm was the German physicist who developed the relationship between current and voltage for a resistor. This relationship is called as Ohms law, which was given by the German physicist. Now, what does Ohm's law say? Ohm's law says that, the voltage V across a particular resistor is directly proportional to the current I , which is flowing through that resistor. So, you can simply represent that V is directly proportional to current I .

Now, Ohm define one constant, which is called proportionality constant for this particular equation and that was represented by R and from there the equation came $V = iR$. So, this proportionality constant was the resistance of that element through which the current is flowing. So, now from the above equation you can simply say that resistance R is nothing but, voltage V divided by current. So, for 1 Ohm, what you will say? You will say 1 Ohm is nothing but 1 Volt per Ampere.

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RESISTANCE (CONT...)

- The value of R can range from zero to infinity.
- An element with $R = 0$ is called a short circuit.
- For a short circuit,
$$v = iR = 0$$
- The short circuit voltage across an element is zero.
- Similarly, an element with $R = \infty$ is known as open circuit.
- For an open circuit,
$$i = \lim_{R \rightarrow \infty} \frac{v}{R} = 0$$
- Thus, for an open circuit the current through the element is zero.

Now, the value of resistance R can change from zero to infinity. Now, if resistance value R is zero it means that, that particular element is short circuit. So, ideally if you take electrical wire you assume that the value of R is zero. Because if you connect that wire through between 2 nodes then the 2 nodes will be short circuited. However, this is only in the ideal condition, because in practical scenario all electrical wires have their own resistance. Although it is small as compared to the other resistive element, but it is still need to be considered. But under ideal condition we assume that the value of that element is zero. So, when the value of R is zero, we generally call it as a short circuit condition. So, what will happen under a short circuit condition? The value of V that is $I R$ will be equal to zero. So, it means that under short circuit condition the voltage across the element would be zero.

Similarly, if the value of R is infinity, because R can range from zero to infinity, under next boundary condition that is R is equal to infinity, you will consider the circuit as open circuit. Under that open circuit condition what would be the current I ? You can find out the value of I is nothing but $\lim_{R \rightarrow \infty} \frac{v}{R}$ and the value of this is equal to zero. So, it means that under open circuit condition the current flowing through that element would be zero.

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CONDUCTANCE

- Another useful element in circuit analysis is the reciprocal of resistance R , known as conductance G .
- It is defined as a measure of how well an element can conduct electric current.
- The unit of conductance is siemens (S) or mho (Ω).
- It can be expressed mathematically as,
$$G = \frac{1}{R} = \frac{i}{v}$$
- Thus the unit of conductance can be expressed as,
$$1S = 1\Omega = 1A/V$$
- The same resistance can be expressed in terms of ohms or siemens. For example, 10Ω is same as 0.1Ω .

Handwritten red notes on the slide:
- $\Omega \rightarrow mho$
- $R = v/i$
- $G = i/v$

Now, another useful element in the circuit analysis is reciprocal of the resistance which is known as conductance and represented by G . Now, it is defined as a parameter that identifies how well an element can conduct the electric current. So, it is just opposite to the resistance R . R is nothing but the property of any element to resist the flow of current while, conductance says how well that particular element can allow the flow of current.

So, the unit of conductance is given in siemens or alternatively you can say as mho. Mho is nothing but the opposite of ohm. Now, it can be expressed mathematically as,

$$G = \frac{1}{R} = \frac{i}{v}$$

So, the conductance now can be expressed as 1 siemen or 1 mho or as 1 ampere per volt. Now, same resistance can be expressed in terms of ohm or resistance and Ohm or Siemens. That means if 1 resistance is having 10 Ohm as resistance in the same way you can say, that element is having 0.1 mho as conductance.

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POWER DISSIPATED IN A RESISTOR:

- The power dissipated in resistor can be expressed in terms of the resistance, R .
- In the previous lecture we had derived the equation for power as $p = vi$.
- From Ohm's law we know that $v = iR$.
- Combining the above two equations, we obtain

$$p = vi = i^2R = \frac{v^2}{R}$$

- The power dissipated can also be expressed in terms of conductance as,

$$p = vi = v^2G = \frac{i^2}{G}$$

Now, let us see, how you will calculate the power dissipated in a resistor. The power dissipated in resistor can be expressed in term of the element like resistance R and the voltage, and current. So, now in first lecture we derived the equation of power that was $p = vi$. Now from ohm's law what we have got, we got $v = iR$. So, if you combine these you will get the value of power

$$p = vi = i^2R = \frac{v^2}{R}$$

So, alternatively the power dissipated can also be expressed in term of conductance. So, wherever you see R you just replace R by $1/G$, you will get the value of power in term of conductance as,

$$p = vi = v^2G = \frac{i^2}{G}$$

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EXAMPLE:

❖ A 30 V voltage is applied across a resistor of resistance $5 \text{ k}\Omega$. Calculate the current, the conductance and the power absorbed by the resistor?

SOLUTION: The voltage across the resistor $v = 30 \text{ V}$

$$i = \frac{v}{R} = \frac{30}{5 \times 10^3} = 6 \text{ mA}$$

The conductance is given by:

$$G = \frac{1}{R} = \frac{1}{5 \times 10^3} = 0.2 \text{ mS}$$

Now, let us take an example to understand better the theory which we just discussed. That is suppose a 30 volt voltage is applied across a resistor of resistance 5 kilo ohm. Calculate the current, conductance and power absorbed by the resistor. So, here voltage across the resistor V is 30 volt then current

$$i = \frac{v}{R} = \frac{30}{5 \times 10^3} = 6 \text{ mA}$$

Now, what would be the conductance?

$$G = \frac{1}{R} = \frac{1}{5 \times 10^3} = 0.2 \text{ mS}$$

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The power dissipated or absorbed by the resistor can be evaluated using any of the formulas discussed in the lecture, as follows:

$$p = vi = 30 * (6 * 10^{-3}) = 180 \text{ mW}$$

or

$$p = i^2 R = (6 * 10^{-3})^2 * 5 * 10^3 = 180 \text{ mW}$$

or

$$p = v^2 G = (30)^2 * 0.2 * 10^{-3} = 180 \text{ mW}$$

Now, let us try to find the power dissipated or absorb by the resistor. You can use any formula which we have discussed till now. Let us take $p = vi$, so when you put value v and i you directly get the value of power dissipated that is 180 milliwatt. Similarly, $p = i^2 R$, so put the value of current i . So, $i^2 R$ you substitute the value again you will get the same value of power dissipated that is 180 milliwatt.

Now third option is you can calculate with the help of conductance. That is $p = v^2 G$, put the value you will again get the value of 180 milliwatt. So, you can use any formula which you want to use for calculation of power, you will get the same value eventually.

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EXAMPLE:

❖ A voltage source of $20 \sin \pi t$ V voltage is applied across a resistor of resistance $5 \text{ k}\Omega$. Calculate the current through the resistor and the power absorbed by the resistor?

SOLUTION The voltage across the resistor $v = 20 \sin \pi t$ V

$$i = \frac{v}{R} = \frac{20 \sin \pi t}{5 \times 10^3} = 4 \sin \pi t \text{ mA}$$

Hence,

$$\rightarrow p = vi = 80 \sin^2 \pi t \text{ mW} = 20 \sin \pi t \times 4 \sin \pi t$$

Now, let us take another example. Suppose if the voltage source of $20 \sin \pi t$ V is applied across the resistor of resistance $5 \text{ k}\Omega$. How will you calculate the current through resistor and power absorb by the resistor?

Simply use the formula

$$i = \frac{v}{R} = \frac{20 \sin \pi t}{5 \times 10^3} = 4 \sin \pi t \text{ mA}$$

Now, to calculate the value of power p,

$$p = vi = 80 \sin^2 \pi t \text{ mW}$$

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CAPACITANCE

- A capacitor is a passive element designed to store charge in its electric field.
- A capacitor typically is constructed using two conducting plates separated by an insulator/dielectric.
- When a voltage, v is connected to the capacitor a charge q is deposited on one plate and a charge $-q$ is deposited on the other plate.
- Capacitor is therefore said to store charge
- The amount of charge stored is directly proportional to v and is expressed as, $q = Cv$
- C is the constant of proportionality and is known as the capacitance of the capacitor.
- In electric circuits a capacitor is represented as

Handwritten notes: $q \propto v$, $q = C v$

Now, let us consider another element called capacitance. Let us try to understand what is capacitor. So, capacitor is a passive element design to store energy in its electric field. So, capacitor is typically constructed using two conducting plates, separated by an insulator or dielectric. Now, when you apply voltage v across the plates of the capacitor a charge q is deposited on one plate of the capacitor and charge $-q$ is deposited on the other plate of the capacitor.

So, therefore you can say that capacitor is an element which stores charges. Now, what would be the amount of stored charge? That would be directly proportional to voltage v . So, can say that q that is stored charge is directly proportional to v . Now, you can introduce another proportionality constant that is called C . So, here what is C ? C is the constant of proportionality which is known as capacitance of that capacitor and $q = Cv$.

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The slide is titled "CAPACITANCE (CONT...)" and contains the following text:

- Capacitance is therefore defined as the ratio of the charge on one plate of a capacitor to the voltage difference between the two plates, and is measured in farads (F).
- Therefore, 1 farad = 1 coulomb/volt.
- Capacitance of a capacitor also depends on the physical dimensions of a capacitor and is expressed as ,

$C = \frac{\epsilon A}{d}$

where, A is the surface area of each plate, d is the distance between the plates, and ϵ is the permittivity of the dielectric between the plates, measured in F/m.

- The permittivity of free space is 8.85×10^{-12} F/m.

Handwritten notes on the slide include:

- $q = Cv$
- $C = q/v$
- A diagram of a parallel plate capacitor with area A and distance d between plates.

So, how you will define capacitance now? Capacitance can be defined as the ratio of charge on one plate of the capacitor to the voltage difference between the two plates. So, earlier we saw $q = Cv$. So, C would be q by V which is the ratio of charge on 1 plate of the capacitor to the voltage difference between two plates. Now, it is measured in farads. What is the value of 1 farad? 1 farad is nothing but, 1 Coulomb per volt.

Now, capacitance of a capacitor also depends upon its physical dimension. So, if you see the capacitor plates, like if it is two plate capacitor, the area A and the distance between the plates define the value of capacitance of that capacitor. So, how you will define capacitance C ?

$$C = \frac{\epsilon A}{d}$$

where, A is the surface area of each plate, d is the distance between the plates, and ϵ is the permittivity of the dielectric between the plates, measured in F/m. Permittivity of free space is given as 8.85×10^{-12} F/m.

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CAPACITANCE (CONT...)

- To obtain the current-voltage relationship in a capacitor, we use the equations $i = \frac{dq}{dt}$ and $q = Cv$, to obtain.

$$i = C \frac{dv}{dt}$$
- The instantaneous power delivered to the capacitor is

$$p = vi = Cv \frac{dv}{dt}$$
- The energy stored in a capacitor is therefore,

$$w = \int_{-\infty}^t p(\tau) d\tau = C \int_{-\infty}^t v \frac{dv}{d\tau} d\tau = C \int_{v(-\infty)}^{v(t)} v dv = \frac{1}{2} Cv^2 \Big|_{v(-\infty)}^{v(t)}$$

Handwritten red notes on the slide show the derivation of $i = C \frac{dv}{dt}$ from $q = Cv$ by differentiating both sides with respect to time t .

Now, to obtain current voltage relationship in a capacitor, we can use the equation $i = \frac{dq}{dt}$, which we calculated in our first lecture and then $q = Cv$ which we just now saw. So, if you use these 2 equations you can find the value of current I. So, what you have to do? You have to simply take the derivative of both side of the equation with respect of time.

So, this will become $\frac{dq}{dt} = C \frac{dv}{dt}$. C is a constant, so it cannot be differentiated, if you differentiate it will become zero. So, $\frac{dq}{dt} = C \frac{dv}{dt}$. What is $\frac{dq}{dt}$, it is current i.? So, you get $i = C \frac{dv}{dt}$. So, you can easily calculate the value of current i for capacitor.

Now, if you are asked to find the instantaneous power. Then, you have to simply multiply the current which you calculate previously with v, you will get

$$p = vi = Cv \frac{dv}{dt}$$

Now, to calculate the energy stored in the capacitor? You have to just integrate over time this power, you will get the value of total energy stored. So, what would be the value? You integrate from minus infinity to time say t, at particular instant where you want to find out the value of energy stored.

$$w = \int_{-\infty}^t p(\tau) d\tau = C \int_{-\infty}^t v \frac{dv}{d\tau} d\tau = C \int_{v(-\infty)}^{v(t)} v dv = \frac{1}{2} Cv^2 \Big|_{v(-\infty)}^{v(t)}$$

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CAPACITANCE (CONT...)

- Since the capacitor was uncharged at $t = -\infty$, $v(-\infty) = 0$. ✓ v/2 = v

$$w = \frac{1}{2} C v^2 = \frac{q^2}{2C}$$

- The above equation represents the energy stored in the electric field that exists between the plates of the capacitor.
- This energy can be retrieved, since an ideal capacitor cannot dissipate energy.
- In fact, the word capacitor is derived from this element's capacity to store energy in an electric field.
- When the voltage across a capacitor is not changing with time (i.e., dc voltage), the current through the capacitor is zero.
- A capacitor, therefore, acts like an open circuit to dc.

So, it means that your value $v(-\infty) = 0$. And if you take value $v(t)$, v at time at particular time t , then you will say simply as v . So, your total value of energy

$$w = \frac{1}{2} C v^2 = \frac{q^2}{2C}$$

So, using that particular formula also can find out the value of energy W in terms of q and C . So, now this equation represents energy stored in the electric field that exists between the two plates of the capacitor.

So, this energy can be retrieved because it is an ideal capacitor, so it will not dissipate energy by itself. So that is why you can say that capacitor is element having the capacity to store the energy in its electric field. Now, when the voltage across the capacitor is not changing with respect to time the current through the capacitor would be zero. That means the capacitor acts like an open circuit for DC voltage.

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EXAMPLE:

❖ Calculate the charge stored on a 3 pF capacitor with 20 V applied across it? Also, find the energy stored in the capacitor?

SOLUTION: Since $q = Cv$

$$q = 3 \times 10^{-12} \times 20 = 60 \text{ pC}$$

The energy stored is

$$w = \frac{1}{2} Cv^2 = \frac{1}{2} \times 3 \times 10^{-12} \times 20^2 = 600 \text{ pJ}$$

Now, take 1 example, let us calculate the charge stored on 3 pF capacitor with 20 volt applied across it. You just simply use the formula $q = Cv$ and you will calculate the value of

$$q = 3 \times 10^{-12} \times 20 = 60 \text{ pC}.$$

Now, for energy stored you will use

$$w = \frac{1}{2} Cv^2 = \frac{1}{2} \times 3 \times 10^{-12} \times 20^2 = 600 \text{ pJ}$$

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EXAMPLE:

❖ The voltage across a 5 μF capacitor is $v(t) = 10 \cos 6000t$ V? Calculate the current through it?

SOLUTION: The current through a capacitor is given by,

$$i(t) = C \frac{dv}{dt} = 5 \times 10^{-6} \times \frac{d}{dt} (10 \cos 6000t) =$$
$$= -5 \times 10^{-6} \times 6000 \times 10 \sin 6000t = -0.3 \sin 6000t \text{ A}$$

Now, if the voltage across a 5 μF capacitor is $v(t) = 10 \cos 6000t$ V. How you will calculate the current passing through it?

You have to use the formula

$$i(t) = C \frac{dv}{dt} = 5 * 10^{-6} * \frac{d}{dt}(10 \cos 6000t) = -5 * 10^{-6} * 6000 * 10 \sin 6000t =$$

$$= -0.3 \sin 6000t \text{ A}$$

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EXAMPLE:

❖ Determine the voltage across a $2 \mu\text{F}$ capacitor if the current through it is $i(t) = 6e^{-3000t} \text{ mA}$? Assume the initial capacitor voltage to be zero.

SOLUTION: The voltage across a capacitor is expressed as,

$$v(t) = \frac{1}{C} \int_0^t i dt + v(0) \text{ and } v(0) = 0$$

$$v = \frac{1}{2 * 10^{-6}} * \int_0^t 6e^{-3000t} dt * 10^{-3} = 1 - e^{-3000t} \text{ V}$$

Handwritten notes on the slide:

- $i = C \frac{dv}{dt}$
- $\Rightarrow \int dv = \int \frac{1}{C} i dt$
- $\Rightarrow v = \frac{1}{C} \int i dt$

Now, if you are asked to determine the voltage across $2 \mu\text{F}$ capacitor if the current through it is $i(t) = 6e^{-3000t} \text{ mA}$. Assume initial capacitor voltage to be zero, so what will happen? You have to

$$v(t) = \frac{1}{C} \int_0^t i dt + v(0) \text{ and } v(0) = 0$$

$$v = \frac{1}{2 * 10^{-6}} * \int_0^t 6e^{-3000t} dt * 10^{-3} = 1 - e^{-3000t} \text{ V}$$

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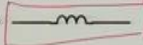
INDUCTANCE

- An inductor is another passive element designed to store energy in its magnetic field.
- An inductor consists of a coil of conducting wire.
- If current is allowed to pass through an inductor, it is found that the voltage across the inductor is directly proportional to the time rate of change of the current.
- The above relation can be mathematically expressed as,

$$v = L \frac{di}{dt}$$

$$v \propto \frac{di}{dt}$$

$$v = L \frac{di}{dt}$$

- L is the constant of proportionality and is known as the inductance of the inductor.
- In electric circuits a inductor is represented as 

Now, let us come to the third element that is inductance. Now, inductor is another passive element which is design to stored energy. But here the stored energy is in the form of magnetic field. Inductor consists of coil of conducting wire and when current is allowed to pass through an inductor, it is found that the voltage across the inductor is directly proportional to time rate of change of current. So that means $v \propto \frac{di}{dt}$. So now if you convert it into equality,

$$v = L \frac{di}{dt}$$

So, this proportionality constant is nothing but, the inductance of that element through which the voltage is measured and current is changing with respect to time. So, $v = L \frac{di}{dt}$ is the property of the inductor and how you will represent this? This is represented in the form of coil. So, the symbol you will see in the literature like this, which is nothing but the symbol for inductor.



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INDUCTANCE (CONT...):

- Inductance is the property whereby an inductor exhibits opposition to the change of current flowing through it, measured in henrys (H).
- Therefore, 1 henry = 1 volt second/ampere.
- Inductance of an inductor depends on its physical dimensions and its construction.
- For a solenoid shaped inductor;


$$L = \frac{N^2 \mu A}{l}$$

where, N is the number of turns, l is the length, A is the cross-sectional area, and μ is the permeability of the core.

Now, what is inductance? Inductance is the property where by an inductor exhibit opposition to the change in current flowing through it and is measured in henrys. So, what is 1 henry? 1 henry is nothing but 1 volt second per ampere.

Inductance of inductor also depends upon the physical dimension. So, suppose if you have a coil and you are asked to find out the value of inductance. See coil will have cross sectional area say it is A , and length is l . So, for this type of inductor your inductance value

$$L = \frac{N^2 \mu A}{l}$$

N is the number of turns, A is the cross sectional area, l is the length of the inductor, and μ , what is μ ? μ is the permeability of the core of the inductor.

So, with this you can calculate the value of

$$L = \frac{N^2 \mu A}{l}$$

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INDUCTANCE (CONT...)

- The current-voltage relationship of an inductor, is expressed as,

$$di = \frac{1}{L} v dt$$
Handwritten note: $v = L \frac{di}{dt}$
- The instantaneous power delivered to the inductor is

$$p = vi = L \frac{di}{dt} i$$
Handwritten note: Inductor
- The energy stored in a capacitor is therefore,

$$w = \int_{-\infty}^t p(\tau) d\tau = L \int_{-\infty}^t i \frac{di}{d\tau} d\tau = L \int_{i(-\infty)}^{i(t)} i di = \frac{1}{2} Li^2 \Big|_{i(-\infty)}^{i(t)}$$

So, now what can you write? You can write

$$di = \frac{1}{L} v dt$$

So, to find out the power delivered to the inductor, you will write

$$p = vi = L \frac{di}{dt} i$$

Now, if you are asked to find out how much energy has been stored in a

$$w = \int_{-\infty}^t p(\tau) d\tau = L \int_{-\infty}^t i \frac{di}{d\tau} d\tau = L \int_{i(-\infty)}^{i(t)} i di = \frac{1}{2} Li^2 \Big|_{i(-\infty)}^{i(t)}$$

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INDUCTANCE (CONT...)

- Since the current at $t = -\infty$ is zero, $i(-\infty) = 0$.

$w = \frac{1}{2} Li^2$ ✓

$v = L \frac{di}{dt}$

- The above equation represents the energy stored in the magnetic field of an inductor.
- The voltage across an inductor is zero when the current through the inductor is constant.
- An inductor, therefore, acts like a short circuit to dc.
- An important property of the inductor is its opposition to the change in current flowing through it.
- The current through an inductor cannot change abruptly.
- An ideal inductor, like an ideal capacitor cannot dissipate energy and the stored energy can be retrieved at a later time.

Now, at the initial condition we assume that $t = -\infty$ is zero, $i(-\infty) = 0$, So, finally what we get?

We get the total energy stored is

$$w = \frac{1}{2} Li^2$$

So, above equation represents the total energy stored in the magnetic field of an inductor. So, opposite to what we saw in the capacitor. Capacitor energy is stored in the electric field. But the inductor stores energy in the magnetic field. Now voltage across inductor is zero, it means that current through inductor is constant.

Because,

$$v = L \frac{di}{dt}$$

v is zero means rate of change of current is zero. So, voltage across inductor would be zero. In that case the inductor would act like a short circuit to DC. Now, important property of this inductor is that it will oppose to the change of flow of current through that particular element. So, it means that you can say that current through an inductor cannot change abruptly. Therefore, the ideal inductor, like an ideal capacitor cannot dissipate energy and it will store energy which can be retrieved at later time.

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EXAMPLE:

❖ The current through a 0.1 H inductor is $i(t) = 10te^{-5t}$ A? Find the voltage across it and the energy stored in the inductor?

SOLUTION: Since, $v = L \frac{di}{dt}$ and $L = 0.1$ H

$$v = 0.1 * \frac{d}{dt}(10te^{-5t}) = e^{-5t} + t(-5)e^{-5t}$$
$$= e^{-5t}(1 - 5t) \text{ V}$$

The energy stored in the inductor is given by,

$$w = \frac{1}{2} Li^2 = \frac{1}{2} * 0.1 * 100t^2e^{-10t} = 5t^2e^{-10t} \text{ J}$$

So now let us take 1 example. Suppose if the current through 0.1 H inductor is

$$i(t) = 10te^{-5t} \text{ A.}$$

We need to find the voltage across that inductor. So, what will we do?

We will use the formula that is

$$v = L \frac{di}{dt} \text{ and } L = 0.1 \text{ H.}$$

We then differentiate

$$\frac{d}{dt}(10te^{-5t}) = 10*(e^{-5t} + t(-5)e^{-5t})$$

So, finally what you will get voltage

$$v = 0.1 * \frac{d}{dt}(10te^{-5t}) = e^{-5t} + t(-5)e^{-5t}$$
$$= e^{-5t}(1 - 5t) \text{ V}$$

Now, if you are asked to find the value of energy stored in an inductor. You simply use formula

$$w = \frac{1}{2} Li^2 = \frac{1}{2} * 0.1 * 100t^2e^{-10t} = 5t^2e^{-10t} \text{ J}$$

So, today we saw 3 basic elements of our electrical circuit, that are resistor, inductor, and capacitor. So, we also saw that the property of these 3 elements and also saw what is the ohms

law. So, in next lecture we will try to find out, how you will utilize this knowledge in analyzing the circuit. So, thank you very much.