| **Electric Circuits and Networks** | **31-07-2018** |
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# Lecture 2: Component Models

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In last class, we were discussing that we need models for electrical component. One way may be solving maxwell's equations although it is most accurate But not practical. So we will use simpler models which are more practical to work with. We will develop lumped circuit model analogous to lumped mass approximation of mechanical systems.

**Lumped Mass Approximation:** In mechanics, we assume that every part of the body is experiencing the force at same time. Dimension/shape etc. of the object are irrelevent with respect to law of motion (i.e. you just need mass of object and amount of force applied)

**Distributed System:** Consider we have a long bridge and some force is applied on one side of the bridge. Then it will take some time for that force to effect the other side.In other words the propogation of information is not instantaneous. Such systems will have to be analysed as distributed system and not as a lumped mass system.

**Electromagnetic Field:** Faraday's law

$$\oint E \cdot dl = -\frac{d\phi_B}{dt}$$

where $\phi_B = \int \frac{\partial B}{\partial t} \cdot \widehat{n}\, ds$ is flux of magnetic field.

$$\oint J \cdot \widehat{n}\, ds = \frac{dQ}{dt} = \frac{\partial \phi_D}{\partial t}$$

Changes in electric/magnetic field are propagated instantly to all part of circuit. if

$$\text{delay} \ll \text{Time period of EM wave}$$
$$\text{or equivalently}$$
$$\text{Dimension} \ll \lambda$$

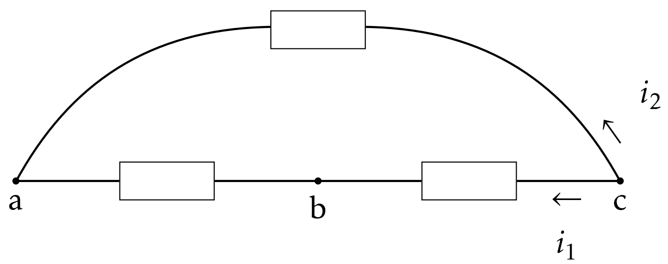
**Example 1:** Let $f = 30KHz$; then $\lambda = \frac{3 \times 10^8}{30 \times 10^3} = 10km$
Practically every circuit will have dimension much less than this wavelength.

**Example 2:** Let $f = 1GHz$; then $\lambda = \frac{3 \times 10^8}{1 \times 10^9} = 0.3m$
There may be circuit (such as transmission lines) where we can not use lumped circuit approxiamtion.

If these conditions are satisfied and the time rate of changeof flux is negligible, we have

$$\oint E \cdot dl = 0$$
$$\oint J \cdot \widehat{n}\, ds = 0 \Rightarrow \frac{dQ}{dt} = 0$$

Consider a general circuit as given below




Where the point **a,b,c** are called **Node**. Nodes connecting component are called **branch**. We assume that wire connecting the components are perfect conductor so there is no valtage drop across them.

For above circuit

$$\int_a^b E \cdot dl + \int_b^c E \cdot dl + \int_c^a E \cdot dl = 0$$

$$(V_a - V_b) + (V_b - V_c) + (V_c - V_a) = 0$$

where $(V_a - V_b) \equiv V_{ab}$ is voltage drop across node **a** and node **b**.

Also at node **c**

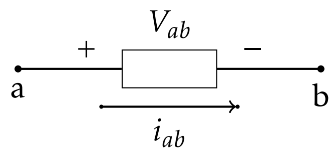
$$\oint J \cdot \widehat{n}\, ds = 0 \Rightarrow i_1 + i_2 = 0$$

For lumped circuits,

**Kirchoff's Voltage Law:** The algebric sum of the branch voltage in any loop at any instant of time is zero.

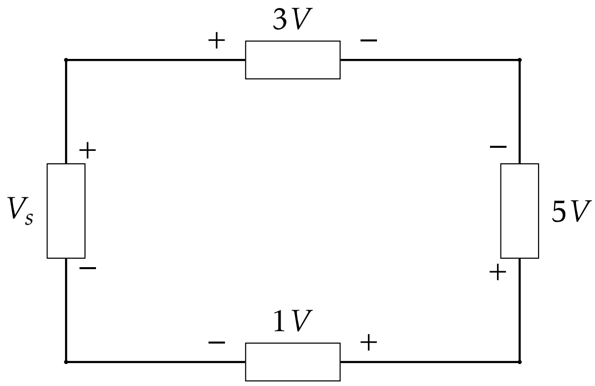
**Kirchoff's Current Law:** The algebric sum of the current leaving any node at any instant of time is zero.

**Reference directions:** it can be arbitrarily assigned to each component such as

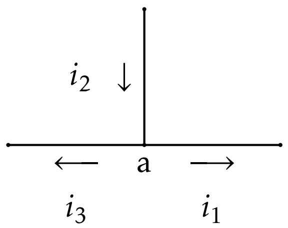



As for the component above node **a** is assumed to be positive w.r.t. node **b** but if get negative value of $V_{ab}$ then we reverse the signs. Similar argument will work for the direction of current.

**Example:** Consider the circuit below



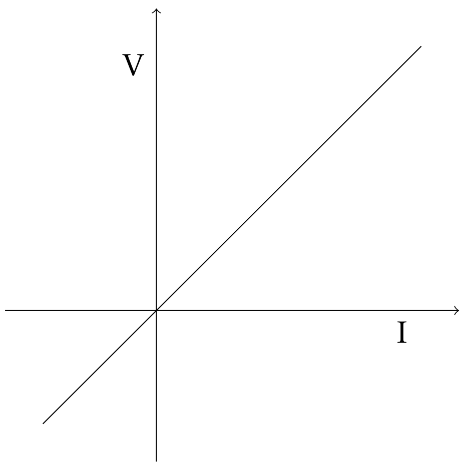

$$V_s = 3 - 5 + 1 = -1$$

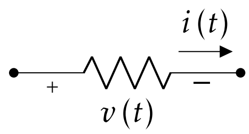



At Node **a**,

$$i_1 + i_3 - 1_2 = 0$$

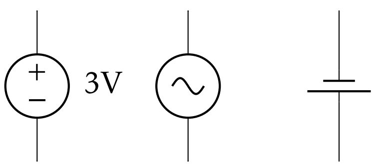
**Resistor:** In case of Time invariant resistor, we have $v(t) = Ri(t)$
if we have time variant resistor such that $R(t) = R_0 + R_1 cosw_1 t$ then $v(t) = (R_0 + R_1 cosw_1 t)\, i(t)$

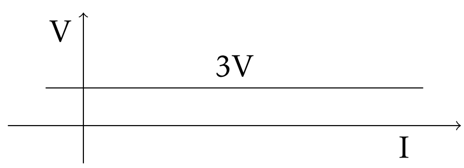



**Independent Sources**

**1. Ideal Voltage Sources:** Voltage across the source is independent of current passing through it.



**2. Ideal Current Sources:** Current through the source is independent of Voltage across it.