EEE-1105

Definitions

① **Charge**: Charge is an electrical property of the atomic particles of which matter consists, measured in coulombs (C).

② **Current**: Electric current is a flow of electric charge. In electric circuit this charge is often carried by moving electrons in a wire. It can also be carried by ions in an electrolyte or by both ions and electrons such as in plasma, measured in amperes (A).

③ **Resistance**: Resistance is a material's tendency to resist the flow of current, measured in ohms (Ω).

④ **Conductivity**: Conductivity is a material's property for which current can flow through the material

⑤ **Conductance**: Conductance is the ability of an element to conduct electric current. It is the reciprocal of the resistance R and is measured in mhos or siemens (S).

$$G = 1/R = I/V$$

⑥ **Energy**: Energy is the capacity to do work, measured in joules (J)

$$W = \int_{t_0}^{t} P\,dt = \int_{t_0}^{t} VI\,dt$$

⑦ **Voltage**: Voltage is the energy required to move a unit charge through an element, measured in volts (V).

⑧ **Power:** Power is the time rate of expending or absorbing energy, measured in watts (W).

$$P = \frac{dW}{dt} = \frac{dW}{dq} \cdot \frac{dq}{dt} = VI$$

⑨ **Circuit:** An electric circuit is a path in which electrons from a voltage or current source flow.

⑩ **Short Circuit:** The circuit which has 0 resistance i.e. $R = 0$, is called a short circuit.

⑪ **Open Circuit:** The circuit which has infinite resistance (i.e. $R = \infty$), is called an open circuit.

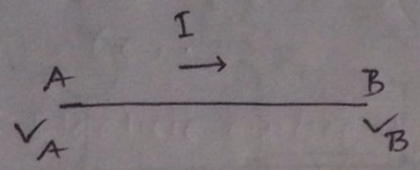
⑫ **Linear Circuit:** Linear circuit is an electric circuit where the input sinusoidal wave of frequency f gives a stead state output. This circuit follows Ohm's law and the value of electronic components (resistance, capacitance, inductance) doesn't change with the level of voltage or current in circuit.

⑬ **Non-Linear Circuit:** The circuit in which the parameter value changes with respect to current and voltage. This circuit doesn't follow Ohm's law and V-I characteristics is not a straight line.

⑭ **Bilateral Circuit:** The circuit which behaves the same way if it is connected in the opposite direction. For example, a resistor behaves the same way no matter if it is connected left-to-right or right-to left. In contrast, a diode is not a bilateral component because it conducts current in one direction, doesn't conduct in the other.

Statement / Explanation

① **Ohm's Law:** Ohm's law states that the current flowing through a conductor is directly proportional to the voltage/potential difference between two points of the conductor.



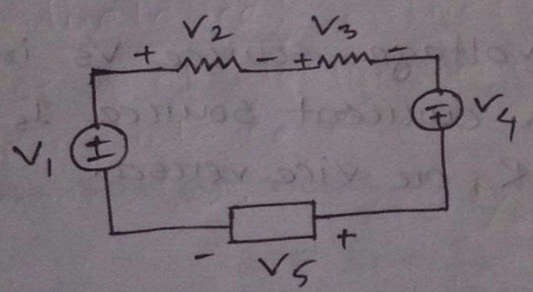
$$V = V_A - V_B$$

$$\therefore I \propto V$$

$$\Rightarrow I = \frac{1}{R} V$$

$$\Rightarrow V = IR$$

② **KVL:** KVL states that the algebric sum of all voltages around a closed path (or loop) is zero.



According to KVL,

$$\sum_{i=1}^{n} V_n = 0$$

i.e. $-V_1 + V_2 + V_3 - V_4 + V_5 = 0$

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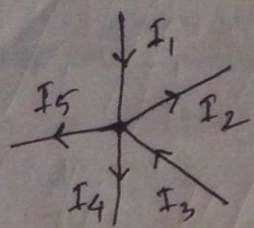
③ **KCL**: KCL states that the algebric sum of currents entering and leaving a node (or a closed boundary) is zero.

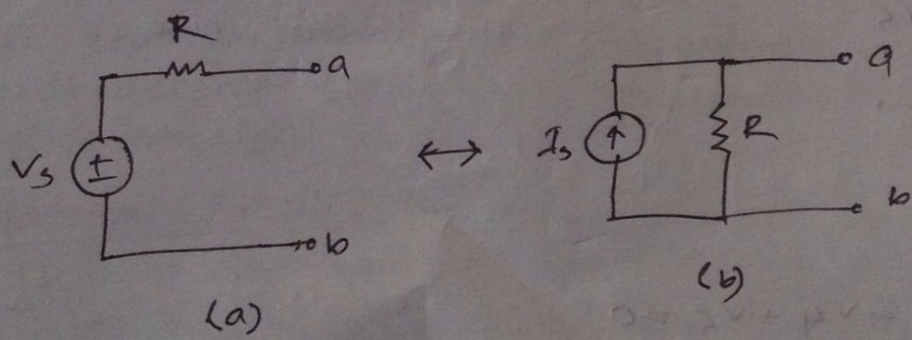


According to KCL,

$$I_1 + I_3 = I_2 + I_4 + I_5$$

i.e. $\sum_{i=1}^{n} I_n = 0$

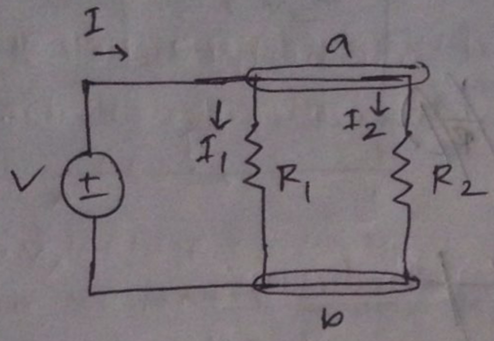
④ **Source Transformation Theorem**: Source transformation is the process of replacing a voltage source V_s in series with a resistor R by a current source I_s in parallel with the ~~Res~~ resistor R, or vice versa.



Two circuits in Fig (a) & (b) are equivalent.

The arrow of the current source is directed toward the positive terminal of the voltage source. Source transformation can't be applied when either $R = 0$ or $R = \alpha$.

(6) Proof of Current Divider Rule:



Consider this circuit where two resistors R_1 & R_2 are connected in parallel and therefore have the same voltage ~~acer~~ across them. From Ohm's law,

$$V = I_1 R_1 = I_2 R_2$$

$$\text{or, } I_1 = \frac{V}{R_1} \quad \text{———} \quad (1)$$

$$\text{and } I_2 = \frac{V}{R_2} \quad \text{———} \quad (2)$$

Applying KCL at node a gives the total current I as

$$I = I_1 + I_2$$

$$\Rightarrow I = \frac{V}{R_1} + \frac{V}{R_2}$$

$$\Rightarrow I = V\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$$

$$\Rightarrow I = \frac{V}{R_{eq}} \; ; \quad \text{———} \quad (3)$$

where R_{eq} is the equivalent resistance of R_1 & R_2 in parallel.

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~~(1) ÷ (3) ⇒~~

$$\cancel{\frac{I_1}{I}} = \cancel{\frac{V}{R_1}} \times \cancel{\frac{R_{eq}}{V}}$$

$$\Rightarrow \cancel{\frac{I_1}{I}} = \cancel{\frac{V}{R_1}} \cancel{\left(\frac{1}{R_1} + \frac{1}{R_2}\right)}$$

$$= \cancel{\frac{V}{R_1}}$$

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$\Rightarrow \frac{1}{R_{eq}} = \frac{R_1 + R_2}{R_1 R_2}$$

$$\therefore R_{eq} = \frac{R_1 R_2}{R_1 + R_2}$$

$$(1) \div (3) \Rightarrow \frac{I_1}{I} = \frac{V}{R_1} \times \frac{R_{eq}}{V}$$

$$\Rightarrow \frac{I_1}{I} = \frac{1}{R_1} \times \frac{R_1 R_2}{R_1 + R_2}$$

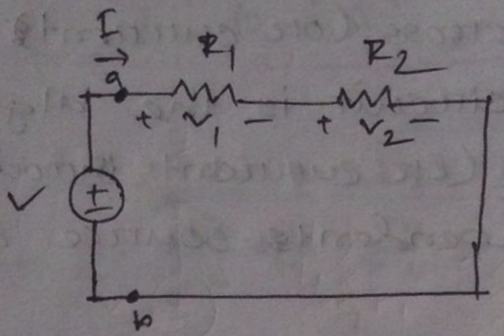
$$\therefore I_1 = \frac{R_2 \times I}{R_1 + R_2}$$

$$(2) \div (3) \Rightarrow \frac{I_2}{I} = \frac{V}{R_2} \times \frac{R_{eq}}{V}$$

$$\therefore I_2 = \frac{R_1 \times I}{R_1 + R_2}$$

(Proved)

⑥ Proof of Voltage Divider Rule :



Consider two resistors R_1 and R_2 are in series connection. As they're in series, current I flows in both of them.
Applying Ohm's Law,

$$V_1 = IR_1 \quad \text{—— (1)}$$

$$V_2 = IR_2 \quad \text{—— (2)}$$

Applying KVL,

$$-V + V_1 + V_2 = 0$$

$$\Rightarrow V = V_1 + V_2$$

$$\Rightarrow V = I(R_1 + R_2) \quad \text{—— (3)}$$

(1) ÷ (3) ⇒ $\dfrac{V_1}{V} = \dfrac{IR_1}{I(R_1+R_2)}$

$$\therefore V_1 = \frac{R_1 \times V}{R_1 + R_2}$$

(2) ÷ (3) ⇒ $\dfrac{V_2}{V} = \dfrac{IR_2}{I(R_1+R_2)}$

$$\therefore V_2 = \frac{R_2 \times V}{R_1 + R_2} \quad \text{(proved)}$$

(7) Superposition Theorem:

The superposition theorem states that the voltage across (or current through) an element in a linear circuit is the algebric sum of the voltages across (or current through) that element due to each independent source acting alone.

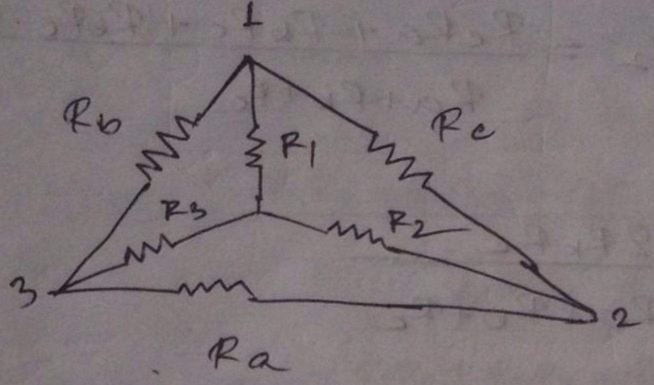
Steps to apply Superposition theorem:

1. Consider one independent source at a time while all other independent sources are turned off. This implies that we replace every voltage source by 0V (or a short circuit) and every current source by 0A (or an open circuit.
   Dependent sources must be left intact.

2. Total contribution can be found by adding algebrically all the contributions due to the independent sources.

Derive the formula of resistors for converting "Δ" to "Y" and "Y" to "Δ"

Δ to Y



Consider 3 resistors R_a, R_b and R_c are in Δ configuration. And R_1, R_2, R_3 are in Y configuration.
For Terminal 1 and 2,

$$R_{12}(Y) = R_1 + R_2$$

$$R_{12}(\Delta) = R_c \parallel (R_a + R_b)$$

$$R_{12}(Y) = R_{12}(\Delta)$$

$$\Rightarrow R_1 + R_2 = \frac{R_c(R_a+R_b)}{R_a+R_b+R_c} \quad \text{—— (1)}$$

Similarly, $$R_2 + R_3 = \frac{R_a(R_b+R_c)}{R_a+R_b+R_c} \quad \text{—— (2)}$$

and $$R_3 + R_1 = \frac{R_b(R_a+R_c)}{R_a+R_b+R_c} \quad \text{—— (3)}$$

$$(3)-(2) \Rightarrow R_3 + R_1 - R_2 - R_3 = \frac{R_aR_b + R_bR_c - R_aR_b - R_cR_a}{R_a+R_b+R_c}$$

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$$\therefore R_1 - R_2 = \frac{R_bR_c - R_cR_a}{R_a+R_b+R_c} \text{ --- } (4)$$

$$(1)+(4) \Rightarrow R_1+R_2+R_1-R_2 = \frac{R_cR_a+R_bR_c+R_bR_c-R_cR_a}{R_a+R_b+R_c}$$

$$\Rightarrow 2R_1 = \frac{2R_bR_c}{R_a+R_b+R_c}$$

$$\therefore R_1 = \frac{R_bR_c}{R_a+R_b+R_c} \text{ --- } (5)$$

Similary, $R_2 = \frac{R_cR_a}{R_a+R_b+R_c}$ --- (6)

and $R_3 = \frac{R_aR_b}{R_a+R_b+R_c}$ --- (7)

$Y \rightarrow \Delta$

$\{(5)\times(6)\}+\{(6)\times(7)\}+\{(7)\times(5)\} \Rightarrow$

$$R_1R_2+R_2R_3+R_3R_1 = \frac{R_aR_bR_c^2}{(R_a+R_b+R_c)^2}+\frac{R_a^2R_bR_c}{(R_a+R_b+R_c)^2}+\frac{R_aR_b^2R_c}{(R_a+R_b+R_c)^2}$$

$$\Rightarrow R_1R_2+R_2R_3+R_3R_1 = \frac{R_aR_bR_c(R_a+R_b+R_c)}{(R_a+R_b+R_c)^2}$$

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$$\Rightarrow R_1R_2 + R_2R_3 + R_3R_1 = \frac{R_bR_c}{R_a+R_b+R_c} \times R_a$$

$$\Rightarrow R_1R_2 + R_2R_3 + R_3R_1 = R_a \times R_1 \quad [\text{From eq}^n\ (5)]$$

$$\therefore R_a = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_1}$$

Similarly, $R_b = \dfrac{R_1R_2 + R_2R_3 + R_3R_1}{R_2}$

and $R_c = \dfrac{R_1R_2 + R_2R_3 + R_3R_1}{R_3}$

(15) Uni-lateral Circuit: Uni-lateral circuit means a circuit consists of uni-lateral elements which allows the current flow only in one direction. For example, a diode allows current only in forward bias mode, not in reverse bias mode.

(16) Supernode: A supernode is formed by enclosing a (dependent or independent) voltage source connected between two non-reference nodes and any elements connected in parallel with it.

(17) Supermesh: A supermesh results when two meshes have a (dependent or independent) current source in common.

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