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ELECTRONICS

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Chapter 1

Basic of Electronics

What is resistance?

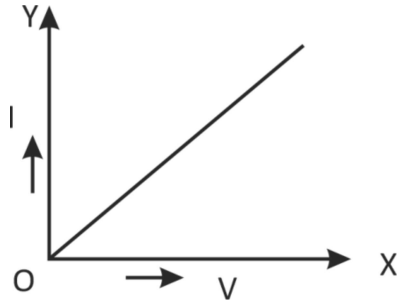
Resistors are electronic components that resist the flow of electricity in a circuit. Resistors are used in electric circuits to adjust current and voltage.

They can be used not only to control the flow of current, but also to distribute voltage in a circuit

The resistance, R of a conductor is defined as the ratio of potential difference, V across the conductor to the current, I flowing through it.

$$\frac{V}{I} = R \; or \; V = IR$$

Ohm the unit of resistance denoted by the Greek character Omega (Ω).



The resistance of conductors is estimated to be

1. The electrical resistance of the material is directly proportional to the length of the material.
2. The electrical resistance of the material is inversely proportional to the material's cross-sectional area.
3. The electrical resistance of the material is dependent on the material's composition.
4. The temperature is a factor.

The resistance of a conducting substance can be stated mathematically as,

$$\boldsymbol{R \propto \frac{l}{a}}$$

$$\boldsymbol{R = \rho \frac{I}{a} \Omega}$$

R denotes the conductor's resistance.

L is the conductor's length.

A = conductor's cross-sectional area.

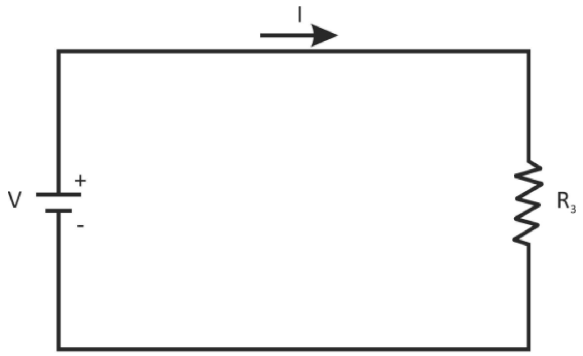
P = the material's proportionality constant, often known as its specific resistance or resistivity.

Resistors in Series

When two or more resistors are connected end to end, they are said to be in series. The resistors could be simple resistors or bulbs or heating elements or other devices

The three resistors R_1, R_2 and R_3 connected in series.

The amount of charge passing through resistor R_1 must also pass through resistors R_2 and R_3 since the charges cannot accumulate anywhere in the circuit



(b) Equivalent resistance (R_3) has the same current

Due to this reason, the current I passing through all the three resistors is the same.

According to Ohm's law, if same current pass through different resistors of different values, then the potential difference across each resistor must be different

Let V_1, V_2 and V_3 be the potential difference (voltage) across each of the resistors R_1, R_2 and R_3 respectively, then we can write $V_1 = IR_1$, $V_2 = IR_2$ and $V_3 = IR_3$.

But the total voltage V is equal to the sum of voltages across each resistor

$$V = V_1 = V_2 + V_3 = IR_1 + IR_2 + IR_3$$
$$V = I(R_1 + R_2 + R_3)$$
$$V = I.R_3$$

Where R_S is the equivalent resistance

$$R_S = R_1 + R_2 + R_3$$

When several resistances are connected in series, the total or equivalent resistance is the sum of the individual resistances

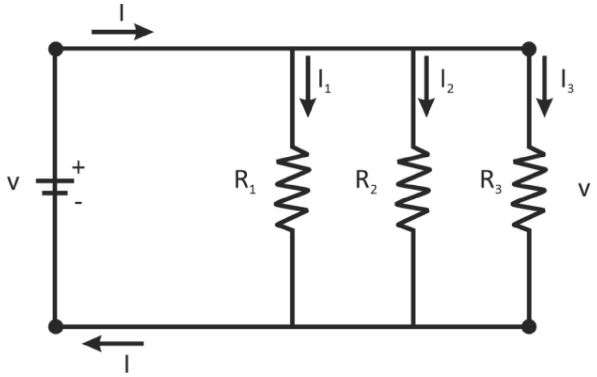
Resistors in Parallel

Resistors are in parallel when they are connected across the same potential difference

In this case, the total current I that leaves the battery is split into three separate paths.

Let I_1, I_2 and I_3 be the current through the resistors R_1, R_2 and R_3 respectively.

Due to the conservation of charge, total current in the circuit I is equal to sum of the current through each of the three resistors.



(a) Three Resistors in parallel

$$I - I_1 + I_2 + I_3$$

Since the voltage across each resistor is the same, applying Ohm's law to each resistor, we have

$$I_1 = \frac{V}{R_1}, I_2 = \frac{V}{R_2}, I_3 = \frac{V}{R_3}$$

Substituting these values in equation

$$I = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3} = V\left[\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right]$$

$$I = \frac{V}{R_p}$$

$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

Here R_P is the equivalent resistance of the parallel combination of the resistors.

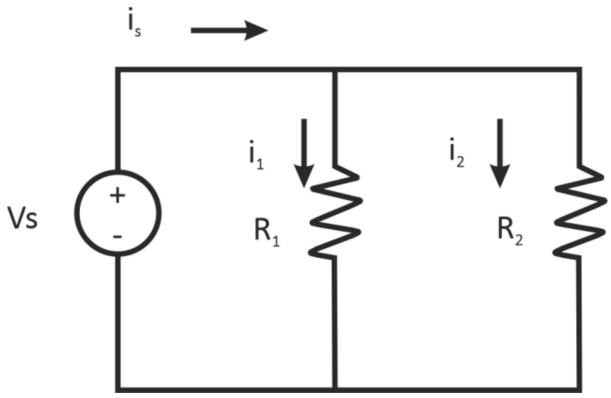
Thus, when a number of resistors are connected in parallel, the sum of the reciprocal of the values of resistance of the individual resistor is equal to the reciprocal of the effective resistance of the combination

The value of equivalent resistance in parallel connection will be lesser than each individual resistance.

House hold appliances are always connected in parallel so that even if one is switched off, the other devices could function properly.

Current Divider Rule (CDR)

Whenever currents has to be divided among resistors in parallel, use current divider rule principle.

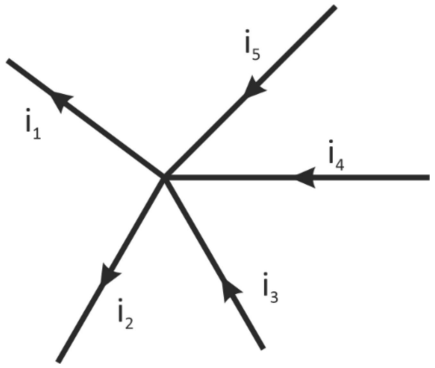


$$i_1 = \frac{R_2}{R_1 + R_2} i_S$$

$$i_2 = \frac{R_1}{R_1 + R_2} i_s$$

Kirchhoff's Current Law (KCL)

This is also called as the law of conservation of charge because charge or current cannot be created or destroyed at the junction or node. It states that the algebraic sum of currents at any node is zero. Thus the current entering at a node must be equal to sum of current out of the node.

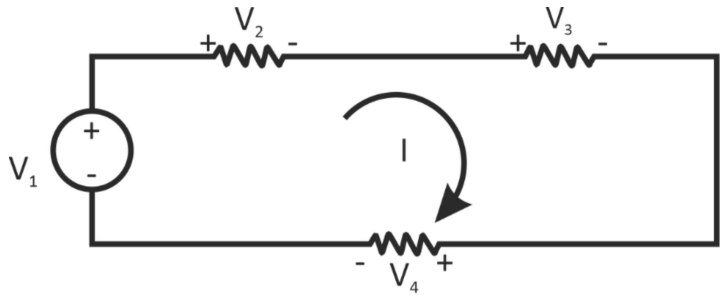


$i_5 + i_4 + i_3 = i_1 + i_2$ $\quad \sum in = \sum out$

(Total current entering) = (Total current leaving)

Kirchhoff's Voltage Law (KVL)

It is an expression for the conservation of energy.



KVL states that algebraic sum of all voltage drops around a closed path (or loop) is zero.

$$\sum v = 0$$

Voltage Drop.

If the current flows from higher potential to lower in an element, then we consider it as a voltage drop.

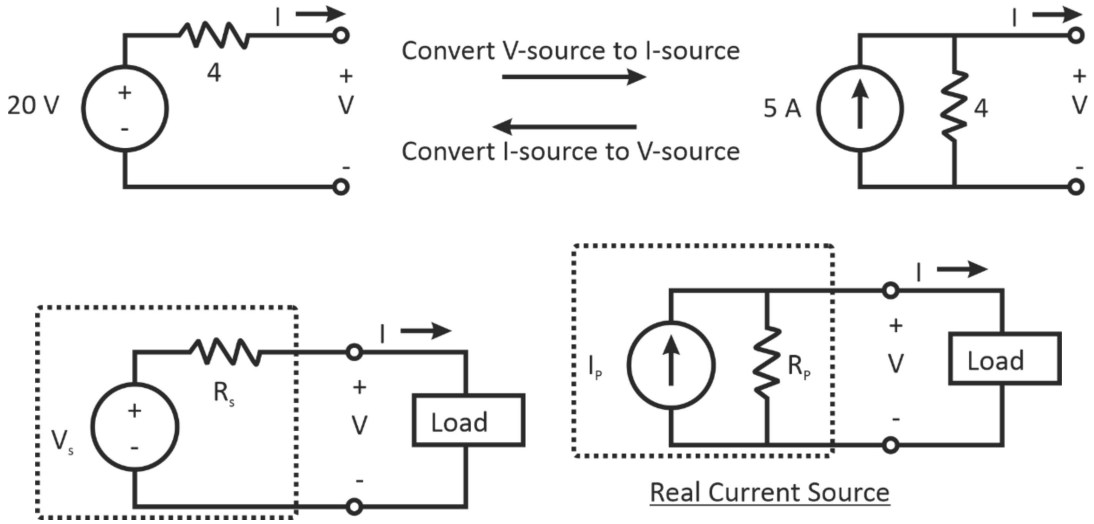
Voltage Rise

If the current flows from lower potential to higher potential, then we consider it as a voltage rise.

Source Transformations (or source conversion)

There are two types of source transformations:

- Transform a real voltage source into a real current source
- Transform a real current source into a real



In order for the two types of sources to be equivalent, they should provide the same voltage and current to any load. This can be accomplished by equating their characteristics. In particular, the x-intercepts, y-intercepts, and slopes should be equal (actually equating any 2 of these 3 items fixes the remaining item).

Source Transformations - Conversion Formulas:

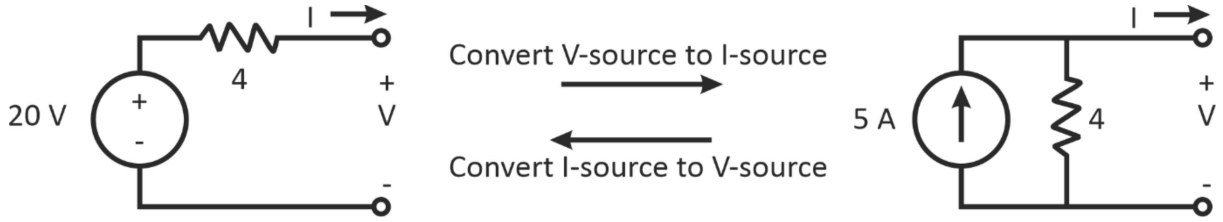
Converting a real voltage source to a real current source:

$\boldsymbol{I_p = \frac{V_s}{R_s}}$ **and** $\boldsymbol{R_p = R_s}$

Converting a real current source to a real voltage source:

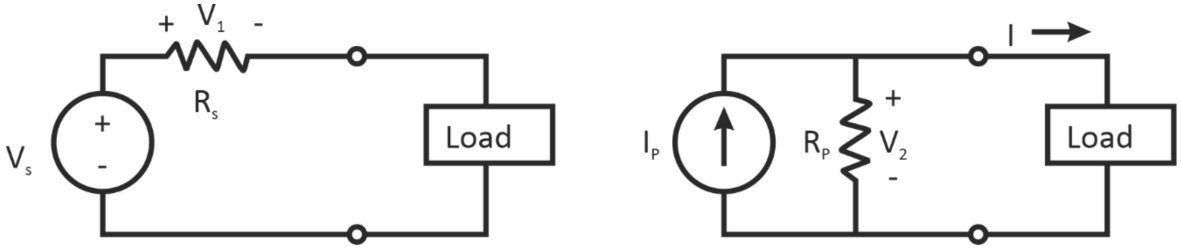
$\boldsymbol{V_s = I_p R_p}$ **and** $\boldsymbol{R_s = R_p}$

Simple Example:



Important notes on source transformations:

1) Transformed sources are equivalent in that they provide the same terminal voltage and terminal current (V and I) to any connected load.
2) Transformed sources are not equivalent internally. For example, the current through or the voltage across R_S and R_p is not the same. To assume that they are the same is a common error. **Example**: In the circuit below, $V_1 \neq V_2$.

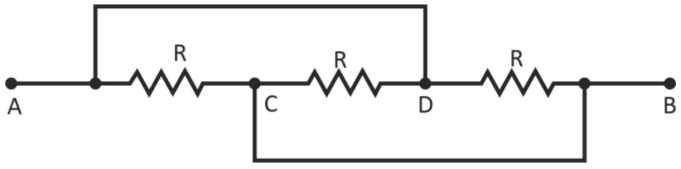


3) All sources are not transformable. Note that a voltage source MUST have a SERIES resistor to be transformable. Note that a current MUST have a PARALLEL to be transformable.
4) Dependent sources can be transformed also.

Node Analysis Method

This method is used to determine the unknown voltage drop around the circuit between two or more nodes.

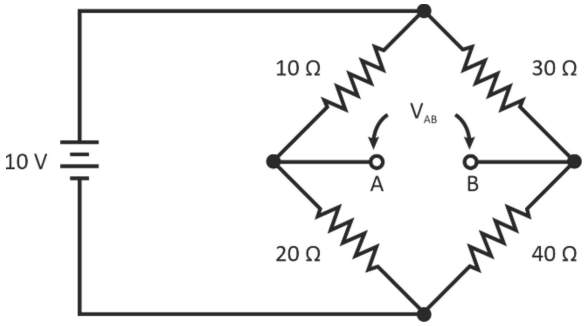
Example: Three equal resistors are connected as shown in fig. Find the equivalent resistance between points A and B.



Solution: one end of each resistor is connected to point A and the other end of each resistor is connected to point B. Hence the three resistors are in parallel.

$$\therefore \frac{1}{R_{AB}} = \frac{1}{R} + \frac{1}{R} + \frac{1}{R} = \frac{3}{R} \; or \; R_{AB} = \frac{R}{3}$$

Example: Find the voltage V_{AB} in the circuit shown in Fig.



Solution: The resistors 10 Ω and 20 Ω are in series and voltage across this combination is 10 V.

$$\therefore V_{AC} = \frac{20}{10+20} \times 10 = 6.667\ V$$

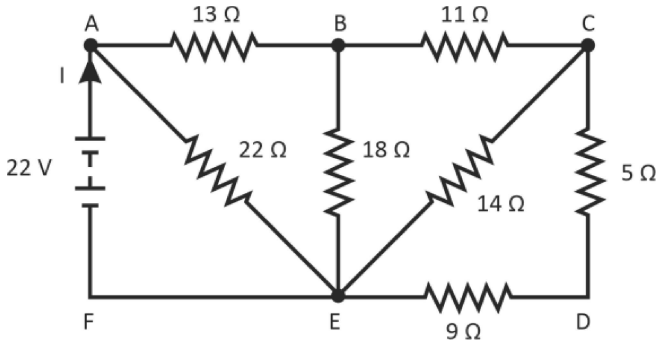
The resistors 30Ω and 40Ω are in series and voltage across this combination is 10 V.

$$V_{BC} = \frac{40}{30+40} \times 10 = 5.714\ V$$

The point A is positive w.r.t. point B.

$$V_{AB} = V_{AC} - V_{BC} = 6.667 - 5.714 = 0.953\ V$$

Example: An electrical network is arranged as shown in Fig. Find the value of current in the branch AF.



Solution: Resistance between E and C,

$$R_{EC} = \frac{(5+9) \times 14}{(5+9)+14} = 7\ \Omega$$

Resistance between B and E,

$$R_{BE} = \frac{(11+7) \times 18}{(11+7)+18} = 9\Omega$$

Resistance between A and E,

$$R_{AE} = \frac{(13+9) \times 22}{(13+9)+22} = 11\Omega$$

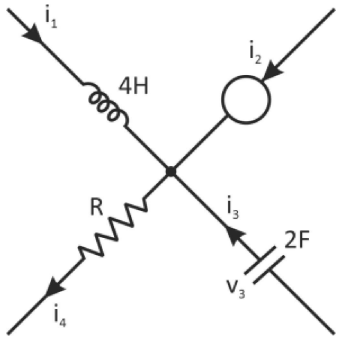
i.e., Total circuit resistance, $R_T = 11\ \Omega$

Current in branch AF, $I = V/R_T = 22/11 = 2A$

Example: In the network shown in Fig., the different currents and voltages are as under:

$$i_2 = 5e^{-2t}; i_4 = 3\sin t\ ; v_3 = 4e^{-2t}$$

Using KCL, find voltage v_1.



Solution: Current through capacitor is

$$i_3 = C\frac{dv_3}{dt} = C\frac{d}{dt}(v_3) = \frac{2d}{dt}(4e^{-2t})$$
$$= -16e^{-2t}$$

Applying KCL to junction A in Fig.,

$$i_1 = i_2 = i_3 + (-i_4) = 0$$

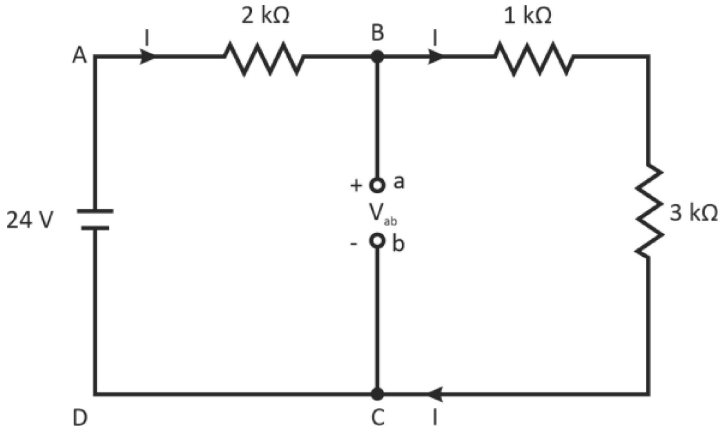
Or $i_1 + 5e^{-2t} - 16e^{-2t} - 3\sin t = 0$

Or $i_1 = 3\sin t + 11\, e^{-2t}$

∴ Voltage developed across 4H coil is

$$v_1 = L\frac{di_1}{dt} = L\frac{d}{dt}(i_1) = 4\frac{d}{dt}(3\sin t + 11e^{-2t})$$
$$= 4(3\cos t - 22e^{-2t}) = 12\cos t - 88\, e^{-2t}$$

Example: Use Kirchhoff's voltage law to find the voltage V_{ab} in fig.



Solution: We shall use Kirchhoff's voltage law to solve this problem, although other methods can be used.

Total circuit resistance, $R_T = 2 + 1 + 3 + 6k\Omega$

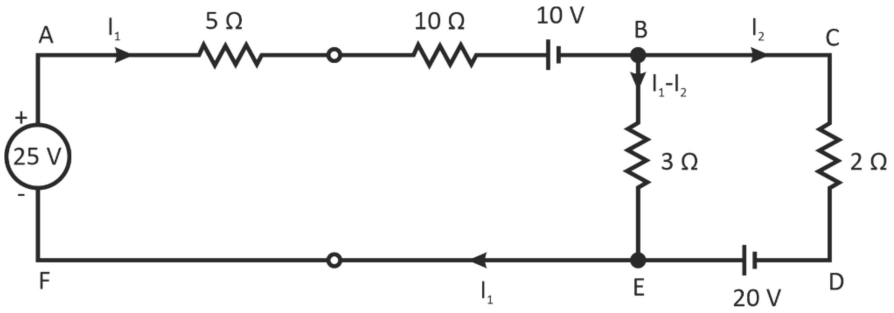
Circuit current, $I = \frac{V}{R_T} = \frac{24\,V}{6\,k\,\Omega} = 4\,mA$

Applying Kirchhoff's voltage law to loop ABCDA, we have,

$$24 - 4mA \times 2k\Omega - * \mathrm{V}_{ab} = 0$$

Or$24 - 8 - V_{ab} = 0 \therefore V_{ab} = 24 - 8 = 16V$

Example: Find the current in and voltage across 2 resistor in Fig.



Solution: We use 5Ω resistor to convert the current source to an equivalent voltage source. The equivalent voltage is

$$E = 5A \times 5\Omega = 25\mathrm{V}$$

Loop ABEFA. Applying Kirchhoff's voltage law to loop ABEFA, we have,

$$-5\, I_1 - 10\, I_1 - 10 - 3(I_1 - I_2) + 25 = 0$$

or

$-18\, I_1 + 3\, I_2 = -15$ .... (i)

Loop BCDEB. Applying Kirchhoff's voltage law to loop BCDEB, we have,

$-2I_2 + 20 + 20 + 3(I_1 - I_2) = 0$ .... (ii)

Or

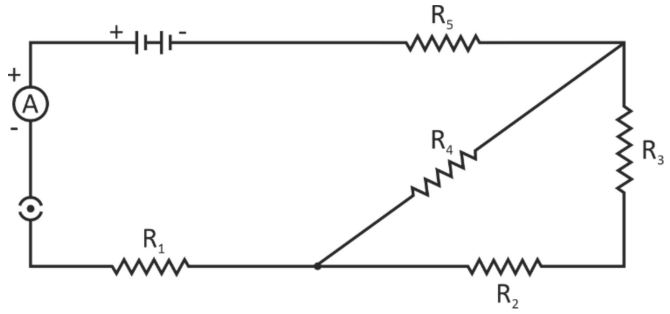
$$3I_1 - 5\,I_2 = -20$$

Solving equations (i) and (ii), we get, I_2 = 5 A.

∴ Current through 2Ω resistor= $I_2 = 5A$

Voltage across 2 Ω resistor $= I_2 \times 2 = 5 \times 2 = 10V$

Consider the following circuit diagram. If $R_1 = R_2 = R_3 = R_4 = R_5 = 3\Omega$. Find the equivalent resistance of the circuit.



Given:- $R_1 = R_2 = R_3 = R_4 = R_5 = 3\Omega$

In circuit, R_2 and R_3 are connected in series,

$$R_1 = R_2 + R_3$$
$$= 3 + 3$$
$$R_1 = 66\Omega$$

Now, R_3 and R_4 are in parallel

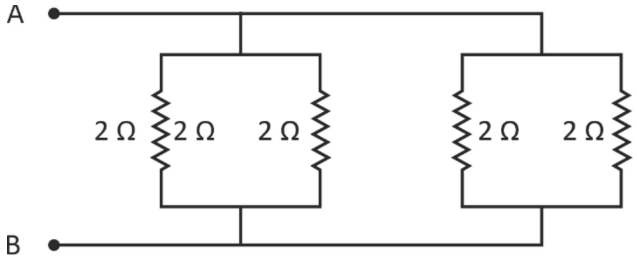
$$\frac{1}{R_p} = \frac{1}{R_{s_1}} + \frac{1}{R_4}$$
$$\frac{1}{R_p} = \frac{1}{6} + \frac{1}{3} \Rightarrow \frac{1}{2}$$
$$R_P = 2\Omega$$

Now, R_1, R_p, R_s are in series combination so equivalent resistance of the circuit is,

$$R_s = R_1 + R_p + R_5$$
$$= 3 + 2 + 3$$
$$R_{eq} = 8\,\Omega$$

Example: Find the equivalent resistance across the two ends A and B of the follow?

Circuit:-



Let the resistances be R_1, R_2, R_3 and R_4

Here, R_1 and R_2 are in parallel combination

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$$
$$\frac{1}{R_{eq}} = \frac{1}{2} + \frac{1}{2}$$
$$R_{eq} = 1\,\Omega$$

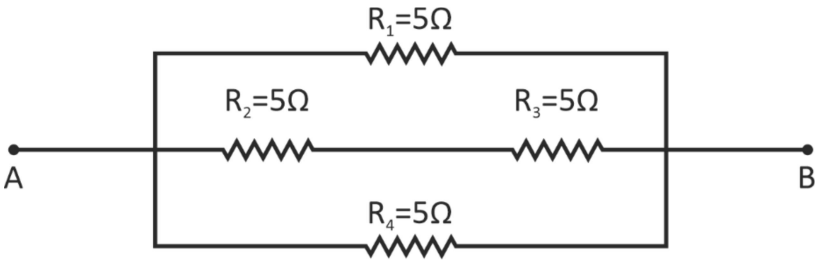
Similarly, R_3 and R_4 are also in parallel combination

$$\frac{1}{R_{eq_2}} = \frac{1}{R_3} + \frac{1}{R_4}$$
$$\frac{1}{R_{eq_2}} = \frac{1}{2} + \frac{1}{2}$$
$$R_{eq_2} = 1\Omega$$

Now, R_{eq_1} and R_{eq_2} are also is parallel combination across AB,

$$R_{AB} = \frac{1}{R_{eq_1}} + \frac{1}{R_{eq_2}} \Rightarrow \frac{1}{1} + \frac{1}{1}$$
$$R_{AB} = \frac{1}{2}$$
$$R_{AB} = 0.5\ \Omega$$

Example: Find the equivalent resistance across the ends AB in the following circuit:-



In the following circuit R_2 and R_3 are in series, so

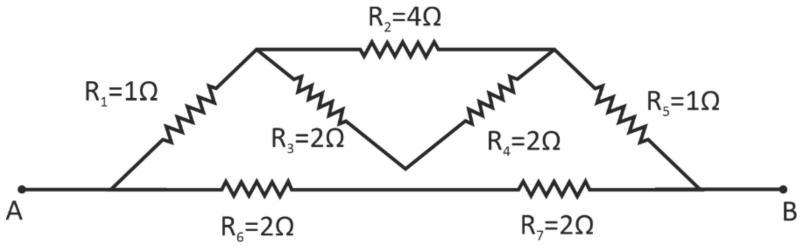
$$R_s = R_2 + R_3$$
$$= 5 + 5$$
$$R_s = 10\ \Omega$$

Now,

R_1, R_s and R_4 are in parallel combination, So

$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_3} + \frac{1}{R_4} \Rightarrow \frac{1}{5} + \frac{1}{10} + \frac{1}{5}$$
$$\frac{1}{R_p} = \frac{5}{10} \Rightarrow R_p = 2\Omega$$

Example: Find the equivalent resistance across AB is the following circuit:-



In the following circuit,

R_3 and R_4 are in series,

$$R_{s_1} = R_3 + R_4$$
$$= 2 + 2$$
$$R_{s_1} = 4\Omega$$

R_{s_1} and R_2 are in parallel combination,

$$\frac{1}{R_{p_1}} = \frac{1}{R_{s_1}} + \frac{1}{R_2}$$