UNIT-I
DC circuits

Voltage:- The difference in potential energy of the charges called the potential difference. potential difference in electrical terminology is known as voltage. It is denoted by 'v' Its units are volts.

$$\boxed{V = \frac{W}{Q}} \quad \text{or} \quad \boxed{v = \frac{dw}{dq}}$$

Where, dw is the small change of energy
dq is the small change in charge.

Where,

energy (W), is expressed in Joules (J).
charge (Q), is expressed in coulombs (C).
Voltage (V), is expressed in Volts (V).

1) If 70J of energy is available for every 30C of charge, what is the Voltage.

$$V = \frac{W}{Q} = \frac{70}{30} = 2.33V$$

Current:- It is defined as the rate of flow of electrons in a conductive or semiconductive material.

$$\boxed{I = \frac{Q}{t}} \quad \text{or} \quad \boxed{i = \frac{dq}{dt}}$$

Where, I is the current
Q is the charge of electrons &
t is the time.

Where, dq is the small change in current
dt is the small change in time.

$$\boxed{1\,\text{coulomb} = 6.25 \times 10^{8}\ \text{electrons.}}$$

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1) Five coulombs of charge flow past in a given point in a wire 2secs, How many amperes of current is flowing?

$$I = \frac{Q}{t} = \frac{5}{2} = 2.5A$$

Power:- It is the rate of change of energy & it is denoted p.
It's units watts.

$$P = \frac{W}{t} \quad \text{or} \quad P = \frac{dw}{dt}$$

$$P = \frac{\text{energy}}{\text{time}}$$

$$P = \frac{dw}{dt} = \frac{dw}{dq} \times \frac{dq}{dt}$$

where, $V = \frac{dw}{dq}$

$i = \frac{dq}{dt}$

$P = vi$ watts.

Energy:- Energy is the capacity for doing work (or), energy is nothing but stored work.

* Energy is measured in Joules (J).

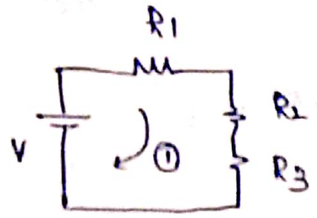
1) What is the power in watts if energy equal to 50J is used in 2.5sec?

$$P = \frac{W}{t} = \frac{50}{2.5} = 20W$$

Electrical Networks:-

* Interconnection of two or more simple circuit elements (voltage source, current, resistor, Inductor & capacitor) is called an electrical network.

* In a network contains at least one closed path, it is called an electric circuit



∴ Here closed paths = 1

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(2)

* Broadly, network elements may be classified in to 4 groups. they are
  1) Active or passive
  2) Unilateral or Bilateral
  3) Linear or Non-linear
  4) Lumped or Distributed

1) Active element :-

* Energy sources are active elements, capable of delivering power to some external devices.

Ex:- Ideal sources, voltage sources & current sources.

passive Elements :-

* The passive elements are, which are capable of receiving the power.

Ex:- Resistor (R), Inductor (L), & capacitor (C).

2) Bilateral :-

* In the bilateral element, the voltage-current relation is same for current flowing in either direction.

Ex:- High conductivity materials.

Unilateral :-

* A unilateral element has different relations b/w voltage & current for the two passive directions of current.

Ex:- Vaccum diodes, silicon diodes.

3) linear Element :-

* An element is said to be linear, if its voltage-current ch's is at all times a straight line through origin

(or)

* Which satisfies the principle of superposition & principle of homogenity is called linear element.

Non-linear Element :-

* An element which doesn't satisfies the super position & homogenity principle.

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4) lumped Elements:-

* The elements which are physically separable

Ex:- Resistor, inductor, capacitor, Transformer.

Distributed Elements:-

* The elements which are not electrically separable.

Ex:- A transmission line which has distributed R, L & C along its length.

Ohm's law:- At constant temperature V is directly proportial to I

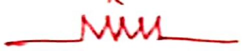
$$V \propto I$$

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

Electrical circuit Element (R, L & C):-

R-parameter:-

* The property of a material to restrict the flow of electrons is called resistance, It is denoted by R



* The unit of resistor is ohm's. (Ω).

$$\boxed{V = IR} \; ; \; I = \frac{V}{R} \Rightarrow R = \frac{V}{I} \; ; \; \frac{1}{R} = G$$

Where G = Conductance its units mho (℧).

* The power absorbed by the resistor is

$$P = VI$$
$$V = IR \qquad \text{(or)} \qquad P = VI$$
$$P = I^2R \qquad\qquad I = \frac{V}{R}$$
$$P = \frac{V^2}{R}$$

* Energy lost in a resistor is

$$W = \int_0^t P\,dt = Pt = I^2Rt$$

$$\boxed{W = I^2Rt \text{ or } \frac{V^2}{R}t}$$

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1) A 10Ω resistor is connected across a 12V battery. How much current flows through the resistor?

$$V = IR$$

$$I = \frac{V}{R} = \frac{12}{10} = 1.2A$$

Inductance parameters:-

* Inductor stores the energy by associated form a current. It is denoted by "L". The unit of inductance is "Henry".

* The wire of a certain length, when twisted in to a coil becomes a basic conductor. If current is made to pass through an inductor an electromagnetic field is formed
* The current-voltage relation is given by

$$\boxed{V = L\frac{di}{dt}}$$

* The power absorbed by inductor is

$$W_L = \int_0^t p\,dt = \int_0^t Li\frac{di}{dt}\cdot dt$$

$$W_L = \int_0^t Li\,di$$

$$\boxed{W_L = \frac{1}{2}Li^2 \text{ Joules.}}$$

1) The current in a 2H inductor varies at a rate of 2A/sec. Find the voltage across the inductor and energy stored in the magnetic field at 2A.

Given data,

$L = 2H$

$\frac{di}{dt} = 2\,A/sec$

$i = 2A$

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

$$V = 2 \times 2 = 4 \text{ Volts}$$

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

$$W_L = \frac{1}{2} \times 2 \times 4$$

$$\boxed{W_L = 4J}$$

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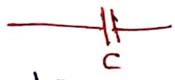
Capacitance parameter:-

* capacitor stores energy by associated form of Voltage. It is denoted by "C", the unit of capacitor is Farad.



* Any two conducting surfaces separated by an insulating medium exhibit, the property of a capacitor. The conducting Surfaces are called electrodes. & insulating medium is called dielectric.

$$C = \frac{Q}{V} \quad \text{or} \quad C = \frac{dq}{dv}$$

$$i = \frac{dq}{dt}$$

$$dq = i\,dt \quad \text{--- (1)}$$

from above equ

$$Q = CV$$

$$dq = C\,dv \quad \text{--- (2)}$$

Sub (1) in (2)

$$i\,dt = C\,dv$$

$$i = C\frac{dv}{dt} \Rightarrow V = \frac{1}{C}\int i\,dt$$

* The power absorbed by the capacitor is given by

$$P = vi$$

$$P = vC\frac{dv}{dt}$$

* The energy stored by the capacitor is

$$W_C = \int_0^t P\,dt$$

$$W_C = \int_0^t vC\frac{dv}{dt} \times dt$$

$$W_C = \int_0^t vC\,dv$$

$$W_C = \frac{1}{2}Cv^2 \text{ Joules}$$

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1) A capacitor having a capacitance 2μF is charged to a Voltage of 1000V, calculate the stored energy in Joules?

$$W_c = \frac{1}{2}CV^2$$

$$W_c = \frac{1}{2} \times 2 \times 10^{-6} \times (1000)^2$$

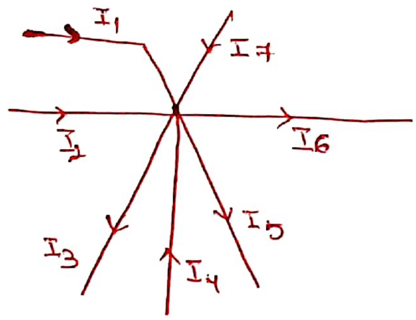
$$\boxed{W_c = 1J}$$

Kirchhoff's laws:-

1) Kirchhoff's current law (KCL)
2) Kirchhoff's Voltage law (KVL)

Kirchhoff's current law (KCL):-

* It states that the sum of the current entering in to any point is equal to the sum of the current leaving that point.



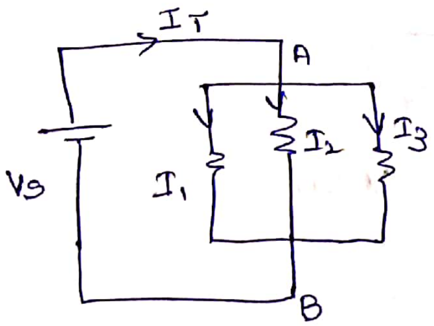
From this diagram

entering currents = leaving currents

$$I_1 + I_2 + I_4 + I_7 = I_3 + I_5 + I_6$$

$$I_1 + I_2 - I_3 - I_4 - I_5 - I_6 + I_7 = 0$$

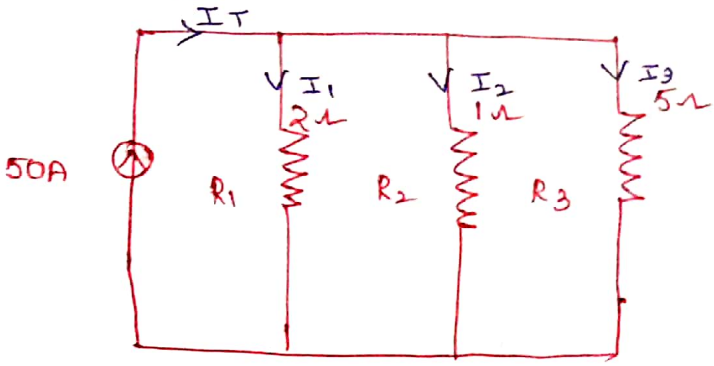
* This means the algebric sum of all the currents meeting at a junction is equal to "zero".



∴ Entering current = leaving current

$$\boxed{I_T = I_1 + I_2 + I_3}$$

1) Determine the currents in all resistors in the circuit shown in fig?



Sol:- * In KCL voltages are same current is dividing

$$I_T = I_1 + I_2 + I_3$$

$$50 = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

$$50 = V\left[\frac{1}{2} + \frac{1}{1} + \frac{1}{5}\right]$$

$$\boxed{V = 29.41V}$$

$$I_1 = \frac{V}{R_1} = \frac{29.41}{2} = 14.705A$$

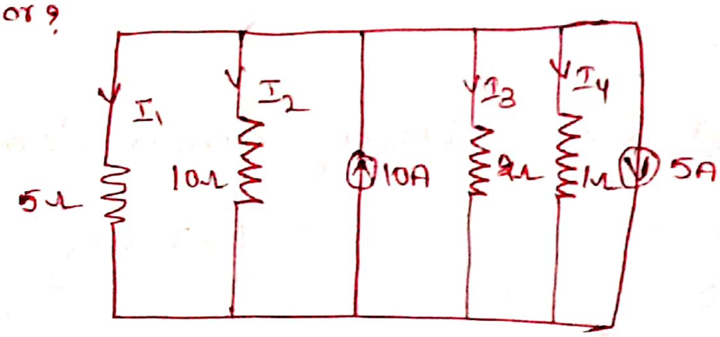
$$I_2 = \frac{V}{R_2} = \frac{29.41}{1} = 29.41A$$

$$I_3 = \frac{V}{R_3} = \frac{29.41}{5} = 5.882A$$

$$I_T = I_1 + I_2 + I_3$$

$$\boxed{50A \cong 49.95A}$$

2) For the circuit shown in fig. Find the current flows through 10Ω resistor?



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$$I_T = I_1 + I_2 + I_3 + I_4$$

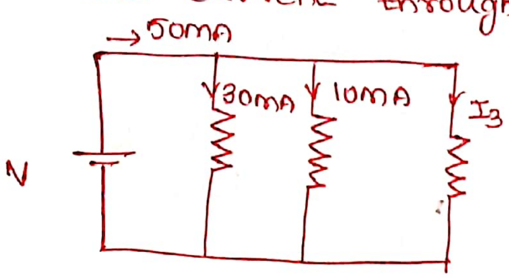
$$10 - 5 = \frac{V}{5} + \frac{V}{10} + \frac{V}{2} + \frac{V}{1}$$

$$V = 2.78V$$

$$I = \frac{V}{10} = \frac{2.78}{10}$$

$$\boxed{I = 0.278A}$$

3) Determine the current through Resistance R_3 in the circuit?



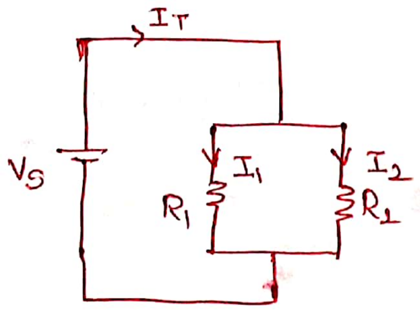
$$I_T = I_1 + I_2 + I_3$$

$$50 = 30 + 10 + I_3$$

$$\boxed{I_3 = 10mA}$$

Current Division Rule:–

* The parallel circuit act as a current divider.
* The total current entering in to the parallel branches is divided in to the branches current according to the resistance values.



Here, In KCL Voltage is same

$$I_1 = \frac{V_S}{R_1} \Rightarrow V_S = I_1 R_1 \quad \text{—— (1)}$$

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$I_2 = \frac{V_S}{R_2} \Rightarrow V_S = I_2 R_2$ — (2)

$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$

R_T (or) $R_{equ} = \frac{R_1 R_2}{R_1 + R_2}$ — (3)

$I_T = \frac{V_S}{R_T} = \frac{V_S (R_1 + R_2)}{R_1 R_2}$ — (4)

Sub (1) in (4)

$I_T = \frac{I_1 R_1 (R_1 + R_2)}{R_1 R_2}$

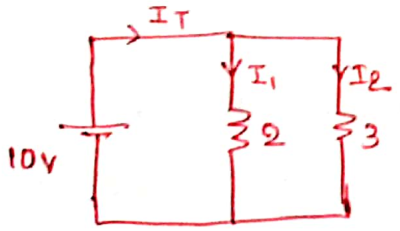
$I_1 = I_T \cdot \frac{R_2}{R_1 + R_2}$ — (5)

Sub (2) in (4)

$I_T = \frac{I_2 R_2 (R_1 + R_2)}{R_1 R_2}$

$I_2 = I_T \cdot \frac{R_1}{(R_1 + R_2)}$ — (6)

1) Determine the current through each resistor in the ckt shown in fig?



$I_T = \frac{V}{R_{equ}}$

$R_{equ} = (2 \parallel 3) = \frac{2 \times 3}{2+3} = \frac{6}{5} = 1.2$

$I_T = \frac{V}{R_{equ}} = \frac{10}{1.2} = 8.33A$

$I_1 = I_T \times \frac{3}{2+3}$

$I_1 = 8.33 \times \frac{3}{5} = 4.998$

$I_2 = I_T \times \frac{2}{2+3}$

$I_2 = 8.33 \times \frac{2}{5} = 3.332$

$I_T = I_1 + I_2$

$8.33 = 4.99 + 3.33 \Rightarrow 8.33 \simeq 8.322$

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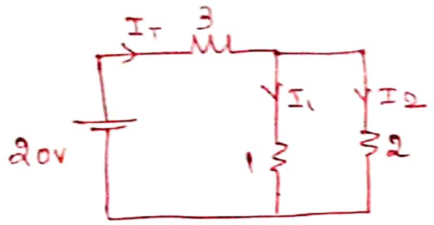
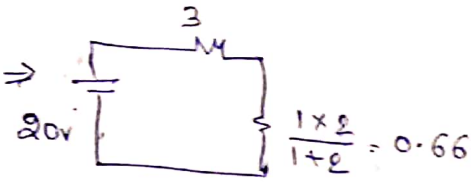
2)



$$I_T = \frac{V}{R_{equ}}$$

$$R_{equ} = (1 \parallel 2) + 3 = \frac{1\times 2}{1+2} + 3$$

$$R_{equ} = 3.66\,\Omega$$



$$I_T = \frac{20}{3.66} = 5.46A$$

$$I_1 = I_T \times \frac{2}{2+1} = 5.46 \times \frac{2}{3} = 3.64A$$

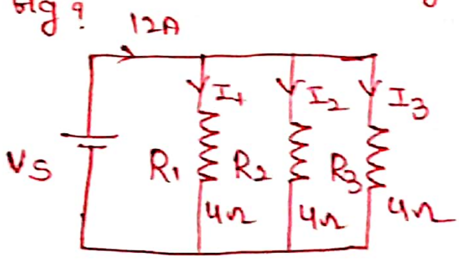
$$I_2 = I_T \times \frac{1}{1+2} = 5.46 \times \frac{1}{3} = 1.82$$

$$I_T = I_1 + I_2$$

$$5.46 \simeq 3.64 + 1.82$$

$$5.46 \simeq 5.46.$$

3) Determine the current through each resistor in the ckt shown in fig?



$$I_1 = I_T \times \frac{(R_2 \parallel R_3)}{R_1 + R_2 + R_3} \Rightarrow 12 \times \frac{\left(\frac{4\times4}{4+4}\right)}{4+2} = 4A$$

$$I_2 = I_T \times \frac{(R_1 \parallel R_3)}{R_2 + (R_1 \parallel R_3)} = 12 \times \frac{\left(\frac{4\times4}{4+4}\right)}{4+2} = 4A$$

$$I_3 = I_T \times \frac{(R_1 \parallel R_2)}{R_3 + (R_1 \parallel R_2)} = 12 \times \frac{\left(\frac{4\times4}{4+4}\right)}{4+2} = 4A$$

$$I_T = I_1 + I_2 + I_3$$

$$\boxed{12A \simeq 12A}$$

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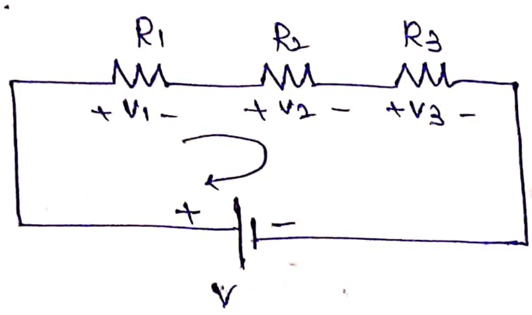
Kirchhoff's Voltage law:—

* Kirchhoff's Voltage law states that the algebric sum of the voltages around any closed path in a circuit is always zero.



Apply the KVL

$$V = V_1 + V_2 + V_3$$

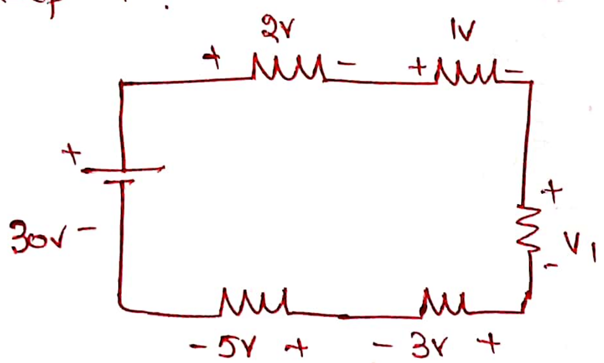
$$V = IR_1 + IR_2 + IR_3$$

$$V = I[R_1 + R_2 + R_3]$$

$$\boxed{I = \frac{V}{R_1 + R_2 + R_3}}$$

* In KVL ~~Voltage in~~ current is same, Voltage is divided.
* In any element, the current always flows from higher potential to lower potential.

1) For the circuit shown in figure, Determine the unknown Voltage drop V_1 ?



$$30 = 2 + 1 + V_3 + 3 + 5$$

$$\boxed{V_1 = 19V}$$

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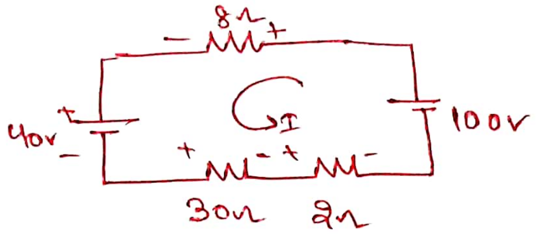
2) In the circuit shown in fig. find the voltage at 30Ω?



Apply KVL

$$100 = 8I + 40 + 30I + 2I$$

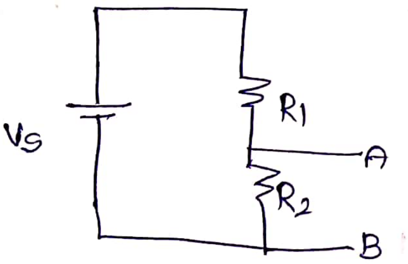
$$I = 1.5A$$

$$V_{30\Omega} = 30 \times 1.5$$

$$\boxed{V = 45V}$$

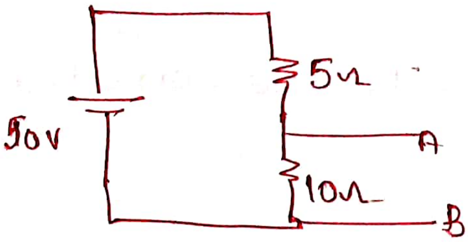
Voltage division rule:-

* The series circuit act as a voltage divider
* Using this principle, different voltages can be obtained from a single source called voltage divider.



$$V_{AB} = V_S \times \frac{R_2}{R_1 + R_2}$$

1) What is the voltage across 10Ω?



$$V_{AB} = 50 \times \frac{10}{10+5}$$

$$V_{AB} = \frac{100}{3} = 33.3V$$

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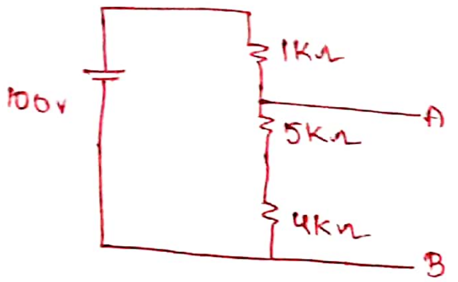
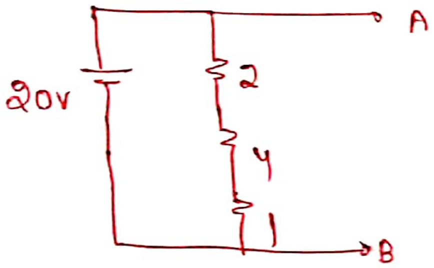


Voltage drop AB is $V_{AB} = 100 \times \frac{5+4}{1+5+4} = 90v$

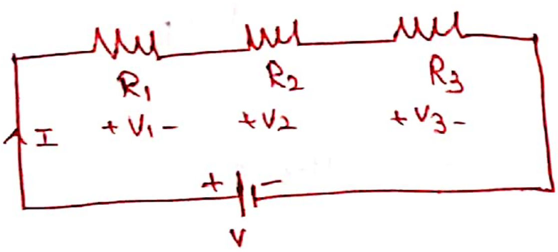
3)



Voltage drop AB is $V_{AB} = 20 \times \frac{2+4+1}{2+4+1} = 20 \times \frac{7}{7} = 20v$

Network Reduction Techniques (R, L & C Series and parallel connection):-

1) Resistor in series:-



The Resistances R_1, R_2 & R_3 are connected in series

Apply the KVL

$V = V_1 + V_2 + V_3$

$V = IR_1 + IR_2 + IR_3$

$V = I[R_1 + R_2 + R_3]$

$R_1 + R_2 + R_3 = R$ (or) R_{equ}

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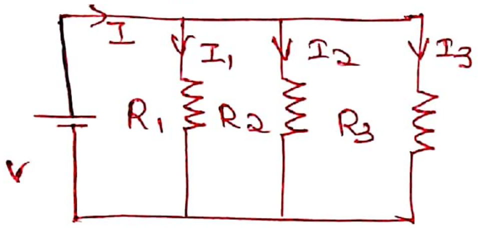
$$R = R_1 + R_2 + R_3 + \cdots + R_n$$

2) Resistors in parallel:–



$$I = I_1 + I_2 + I_3$$

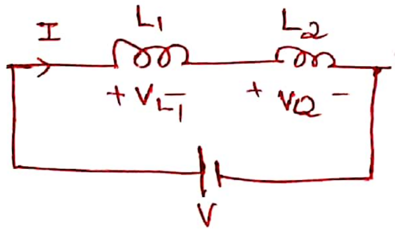
$$I = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

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

$$\frac{1}{R_{equ}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$I = \frac{V}{R_{equ}}$$

3) Inductor in series:–



$$V = V_{L_1} + V_{L_2}$$

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

$$V = L_1\frac{di}{dt} + L_2\frac{di}{dt}$$

$$L\frac{di}{dt} = L_1\frac{di}{dt} + L_2\frac{di}{dt}$$

$$L\frac{di}{dt} = \frac{di}{dt}\left[L_1 + L_2\right]$$

$$L = L_1 + L_2$$

$$L_{equ} = L_1 + L_2 + \cdots + L_n$$

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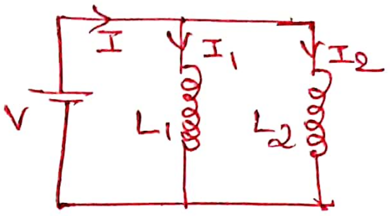
4) Inductor in parallel:-



$$I = I_1 + I_2$$

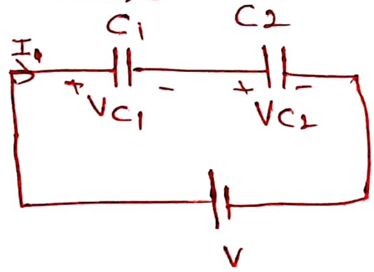
$$V = L\frac{di}{dt} \Rightarrow I = \frac{1}{L}\int V\,dt$$

$$\frac{1}{L}\int V\,dt = \frac{1}{L_1}\int V\,dt + \frac{1}{L_2}\int V\,dt$$

$$\frac{1}{L} = \frac{1}{L_1} + \frac{1}{L_2}$$

$$\boxed{L = \frac{L_1 L_2}{L_1 + L_2}}$$

5) capacitor in series:-



$$V = V_{C_1} + V_{C_2}$$

$$V = \frac{1}{C}\int i\,dt$$

$$\frac{1}{C}\int i\,dt = \frac{1}{C_1}\int i\,dt + \frac{1}{C_2}\int i\,dt$$

$$\frac{1}{C}\int i\,dt = \int i\,dt\left[\frac{1}{C_1} + \frac{1}{C_2}\right]$$

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2}$$

$$\boxed{C = \frac{C_1 C_2}{C_1 + C_2}}$$

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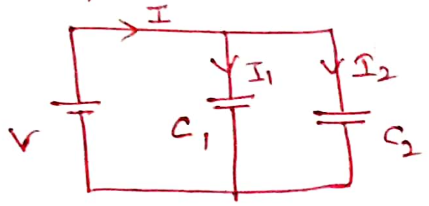
6) Capacitor in parallel:-



$I = I_1 + I_2$

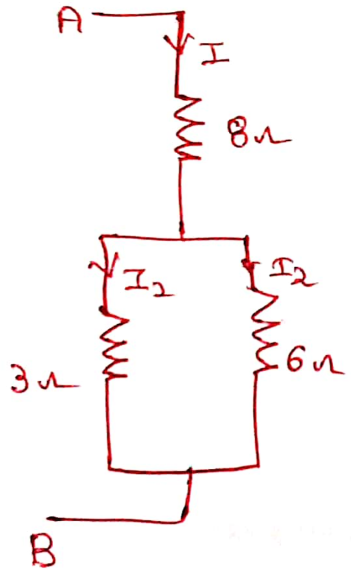
$i = C\frac{dv}{dt}$

$C\frac{dv}{dt} = C_1\frac{dv}{dt} + C_2\frac{dv}{dt}$

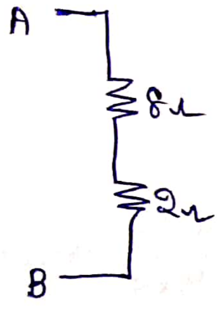
$C\frac{dv}{dt} = \frac{dv}{dt}[C_1 + C_2]$

$\boxed{C = C_1 + C_2}$

1) What is the equivalent resistance b/w A & B of the circuit given below?



3 & 6 are in parallel $= (3 \| 6) = \frac{3 \times 6}{3+6} = 2\Omega$



$\Rightarrow 8 + 2 = 10\Omega$

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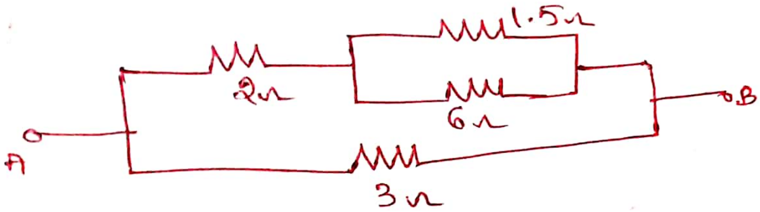
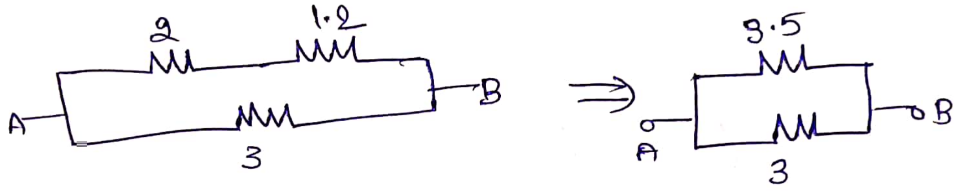
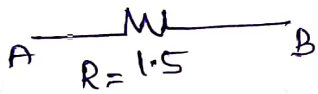
2)



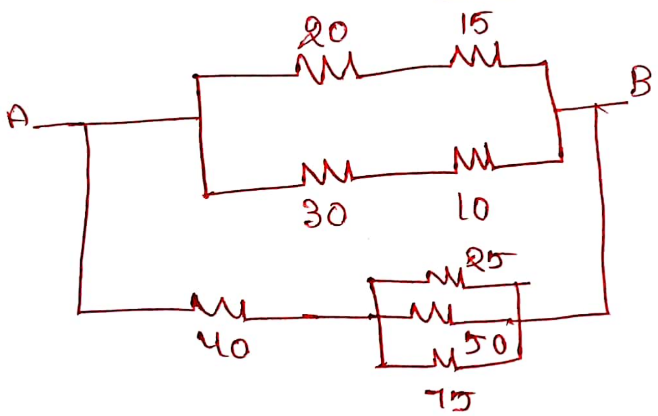
Here, $(1.5 \parallel 6) = \frac{1.5 \times 6}{1.5+6} = 1.2$



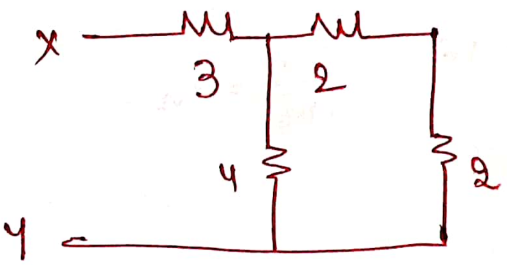
$(3.5 \parallel 6) = \frac{3.5 \times 6}{3.5+6} = 1.5$



3)



4) In fig, find R across x-y terminals?



$((2+2) \parallel 4) + 3 \Rightarrow (4 \parallel 4) = \frac{4 \times 4}{4+4} + 3 = 5$

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