Module 1 Chapter 1

INTRODUCTION

Conventional and non-conventional energy resources

Energy is the capacity or the ability to do work. The energy sources are subdivided into conventional and non-conventional energy sources.

The conventional energy sources are provided by nature but are ~~are~~ present only in restricted quantities. And the non-conventional energy sources are present in unlimited amounts and provided by nature.

Conventional Energy Sources :-

Conventional energy sources are in limited quantities and soon will be depleted with a growth rate of population.

The use of these sources is done for heating, lighting, cooking, running Machinery.

The example for conventional sources is firewood, fossil fuels, etc.

Advantages :→

i) Easily available.

ii) Efficient and good electricity conversion.

iii) low exploration costs.

Disadvantages :→

i) Pollutes the atmosphere.

ii) Destroys natural ecosystems.

iii) Displaces local communities.

iv) Present in restricted quantity

v) Cost is more.

Non-Conventional / Renewable energy sources :-

Non-conventional energy sources are the best alternative to the conventional sources.
Non-conventional sources could be obtained from sun, wind, hot springs and others that support heat and power generation. They are non-polluting and present in abundant quantity within the earth's atmosphere.

→ Solar Energy - The light from the sun is used to generate electricity by trapping the solar cells within the panels. Solar energy is present in abundance although it can be only trapped during the daytime. It is used for lighting, heating etc.

→ Wind Energy - has been used for many years for grinding grains in mills. In recent years it has been used to generate electricity by harnessing the energy of winds by turbines attached to the generators. Usually such wind mills are located near coastal areas & mountains with the high wind flow.

→ Geothermal Energy - The heat aquired from the earth is geothermal energy. In many areas, hot-springs are witnessed as a part of geothermal energy. The heat from within the earth has been used for generating power.

→ Tidal Energy - Tidal waves also generate energy harnessed by erecting dams. The narrow dams of tides and turbines are built near the end of tides and turbines help to capture the energy.

Advantages of Non-conventional Energy sources.

*> They are non-polluting.
*> Available in abundant.
*> Free of cost energy.
*> Harnessing costs are low.
*> low environmental damage.

Dis-advantages of Non-conventional energy sources

*> there availability has the restricted time limits.

Ex:- Solar energy is available only during day time
~~and wind energy is~~

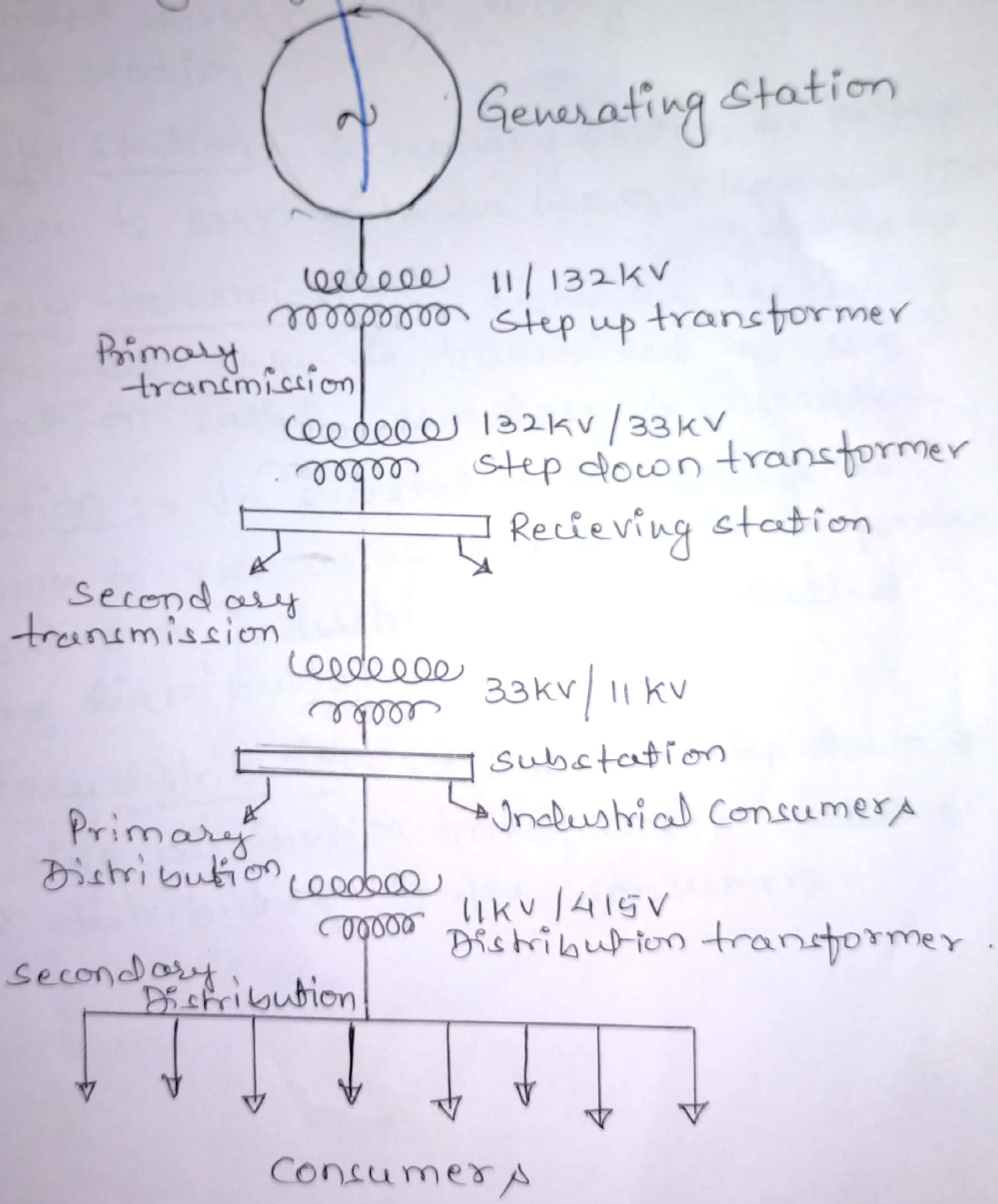
*> Lower efficiency level.
*> Not viable commercially.

Electrical Power System.

It is defined as a network of electrical components used to supply/generate, transmit and consume electric power.

An electrical power system that supplies power to homes and industries for a sizeable region is called electric grid.

Single line Diagram of power transmission & distribution



Generating station :→ In generating station the electrical energy is generated using coal, water, nuclear energy, solar energy, wind energy etc....

Transformers :- It is fed to a step up transformer to increase the voltage level from 11kV to 132kV, to minimize the losses during transmission.

Primary Transmission :- In this high voltage (132kV) transmitted through high voltage cables to the receiving station.

Receiving station :- In receiving station the voltage is step down to 33kV. with the hep of step down transformers.

Secondary transmission :- from the receiving station the 33kV is transmitted to the substation called secondary transmission.

Substation :→ In substation the voltage is step down to 11kV using step down transformer distributed to industrial consumers called Primary distribution.

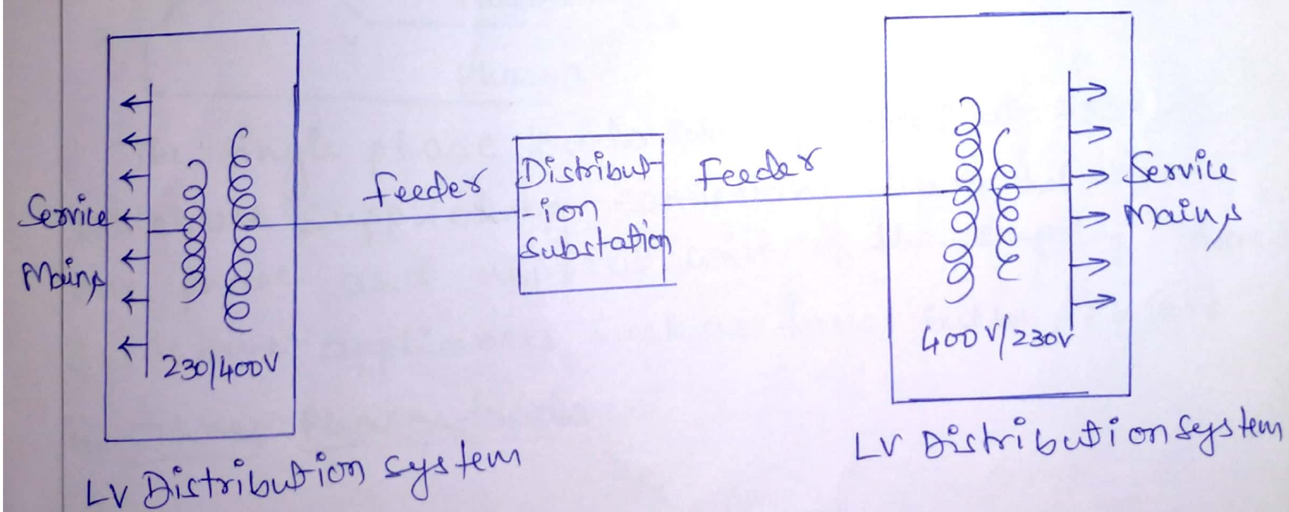
Secondary distribution :→ 11 kV is step down to 400V using distribution transformers, ~~called~~ distributed to the consumers. ~~second~~

Distribution System :- It is defined as the part of electrical power system which distributes electrical power ~~system~~ ~~which~~ ~~distribute~~ for local use.
On the basis of voltage level a distribution system can be classified in two categories viz.
i) low voltage (LV) distribution system
ii) High voltage (HV) distribution system

i) Low Voltage (LV) Distribution System

The distribution system which operates on the voltage levels that are directly utilized without any further reduction. It is also known as low tension (LT) distribution system or secondary distribution system.
"The low voltage distribution system is the part of electrical power distribution network which carries electrical power from distribution transformer to energy meter of consumer.

Block diagram of LV Distribution System.



Components of LV Distribution system :-

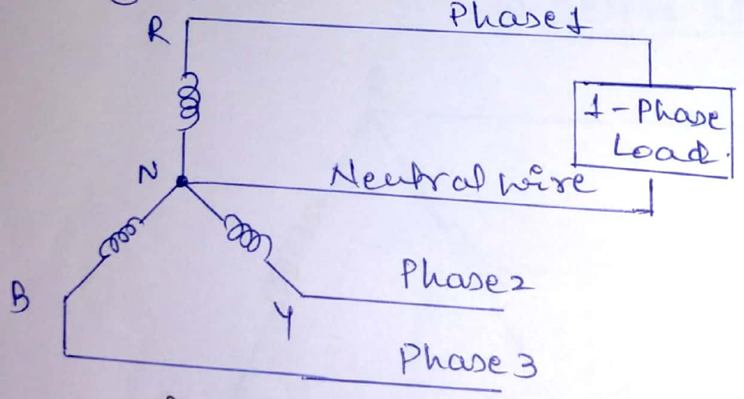
*) Distribution Transformer :- It is a step down transformer which has delta connected primary winding and star connected secondary winding. It sends electrical power to the distributors.

*) Distributor :- It is a conductor from which tappings are taken for supply to the consumers.

*) Service mains :- It is a small cable which connects the distributor to the electricity meter of the consumer.

Types of loads connected to LV Distribution system

i) Single phase loads :-

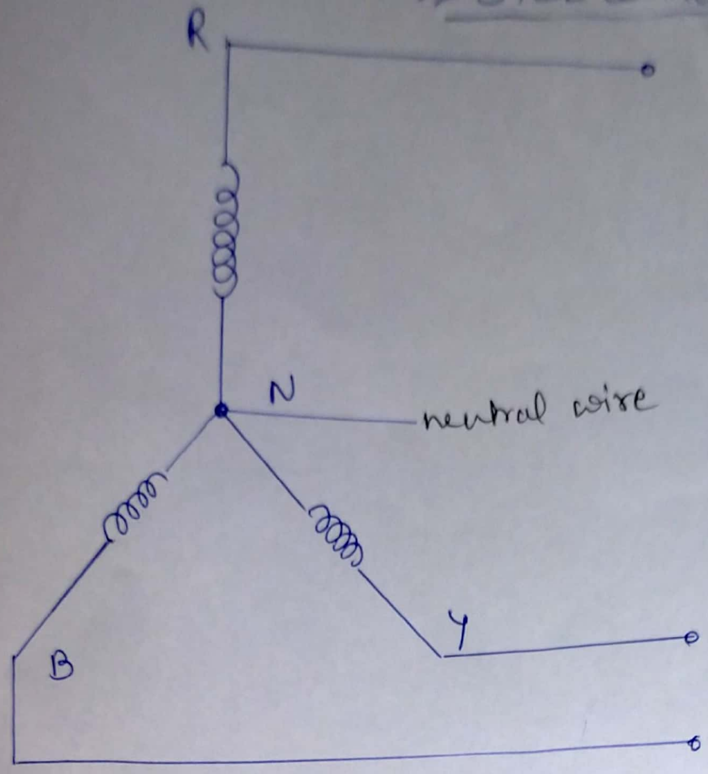


The single phase loads are operated at 230V, which are supplied by connecting them between one phase and neutral wire of the supply system.
Ex:- home appliances such as fans, bulbs, TV etc.

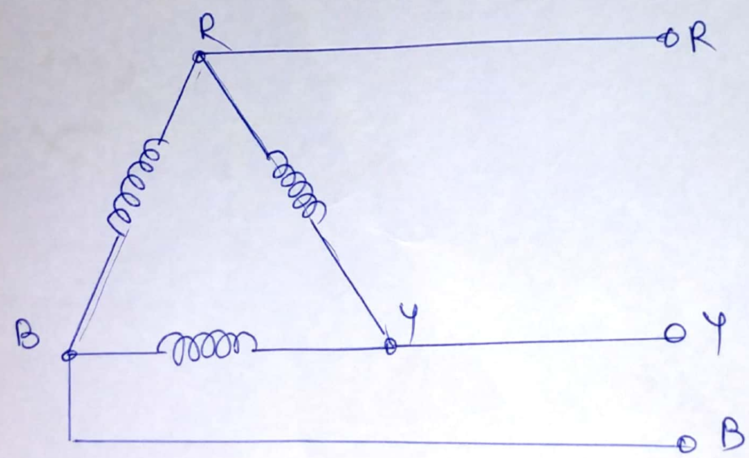
ii) Three Phase loads :-

ii) Three Phase loads

*) star connected 3 Phase loads



*) Delta connected 3 Phase loads



Three Phase loads are operated at 415 V which are supplied by connecting with 3 phase wire (delta connected loads) or three Phase wires with neutral wire (star connected loads).

Ex:- 3 phase Induction motors etc.

Types of 3 Phase loads are

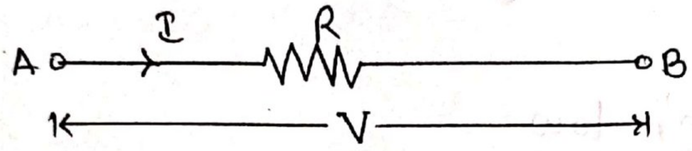
*) star connected 3 Phase loads *) Delta connected 3 Phase loads.

Module I 1) DC CIRCUITS.

I) Ohm's law :-

Q1) state and explain Ohm's law (5marks) June|July 2018

Ans:- Def: Ohm's law states that at constant temperature the current flowing through the conductor is directly proportional to the voltage across the conductor.



ie; $I \propto V$ at constant temperature.

$$I = \frac{V}{R} \text{ Amps}$$

or $V = IR$ Volts.

where R - constant known as resistance.

WKT :- $R = \frac{\rho l}{a}$ ohms (Ω)

where l - length of the conductor in mt.

a - Cross sectional area of the conductor in mt^2.

ρ - resistivity (Ω - mt)

Resistance is the property by which it opposes the flow of the current.

for good conductor $R << 1\ \Omega$

for ideal conductor $R = 0$

for ideal Insulator $R = \infty$.

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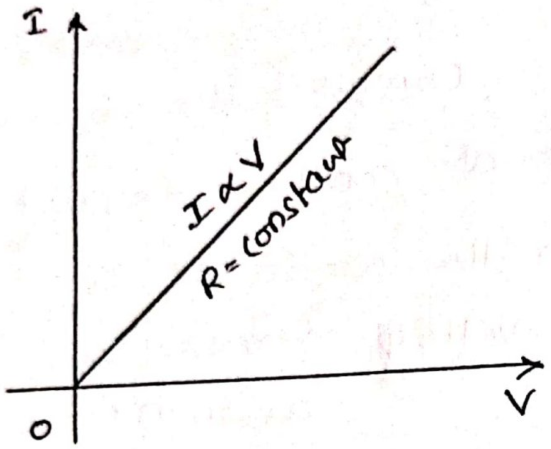
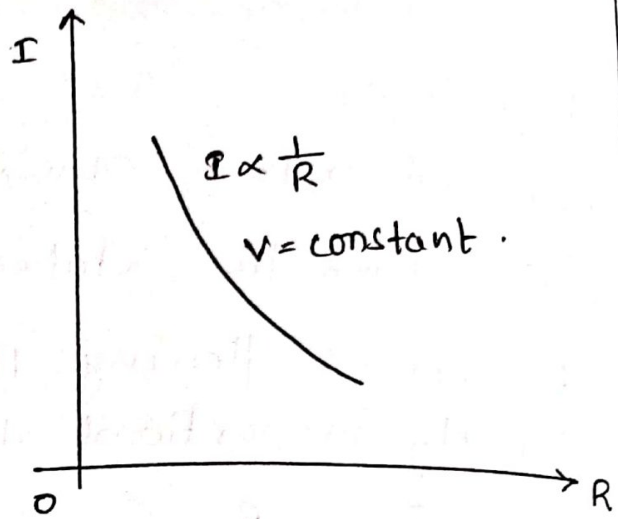
Graphical representation of ohm's law :-





Limitations of Ohm's law

i) Ohm's law does not hold good for Non-metalic conductors.
ex :- Silicon carbide

ii) It does not hold good for Non-linear devices
ex :- Zener diode.

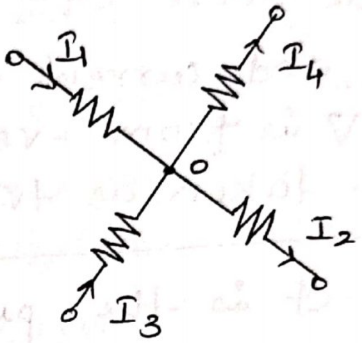
iii) It does not hold good for Arc lamps because of the non linear characteristic of Arc.

Q* Kirchoff's laws :-

Q2) State and explain Kirchoff's laws (6m)

Kirchoff's current law :- (KCL)

It states that the algebraic sum of all the currents meeting at a junction of an electrical circuit is zero.



ie; $\Sigma I = 0$

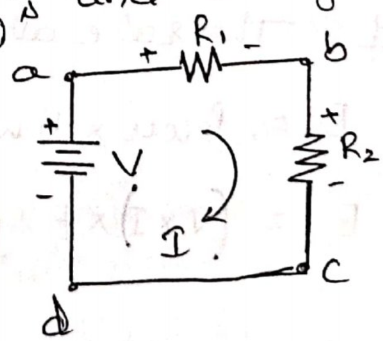
Q $I_1 + I_3 - I_2 - I_4 = 0$

Explaination :-

Consider a junction point 'o'. The currents I_1 & I_3 are entering the junction and the currents I_2 & I_4 are leaving the junction. currents flowing towards the junction is assumed as +ve and leaving the junction as -ve.

Kirchoff's Voltage law :- (KVL)

It states that in any closed loop the algebraic sum of all the emf's and voltage drops is equal to zero.



ie; $\Sigma V + \Sigma IR = 0$

loop abcda

$-IR_1 - IR_2 + V = 0$

$IR_1 + IR_2 = V$

Explaination :-

Consider a closed loop abcda where the two resistors R_1 & R_2 are connected across a voltage V and current I flows in the circuit. ~~It is~~ It is assumed that always current flows through the resistor is from +ve to -ve.

∴ in the above eqn the voltage drops are taken as -ve and current flows through the voltage source V is from -ve to +ve.

∴ V is taken as +ve.

Power :- It is the product of voltage and current applied across the conductor.

ie; $P = V \times I$ watts —— (1)

WKT :- $V = IR$

∴ (1) ⇒ $P = I^2 R$ watts —— (2)

WKT :- $I = \frac{V}{R}$

∴ (1) ⇒ $P = \frac{V^2}{R}$ watts —— (3)

Energy :- The rate at which electrical work is done

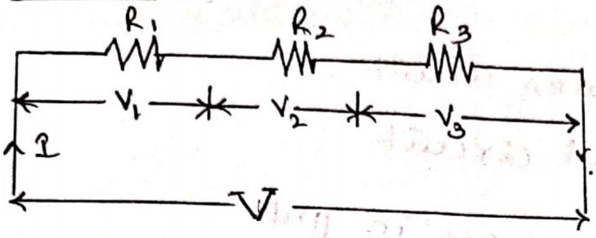
ie; E = Power × time

∴ $E = (V \times I) \times t$ joules or watt-sec.

Series and parallel circuits :-

Q3> List the characteristics of series and parallel circuits (4m)

Series circuit



*> Current flowing through each resistor is same.

*> Voltage drop across each resistor is different.

*> Supply voltage V is the sum of individual voltage drops

ie; $V = V_1 + V_2 + V_3$

*> Equivalent resistance is the sum of individual resistances.

ie; $R_{eq} = R_1 + R_2 + R_3$

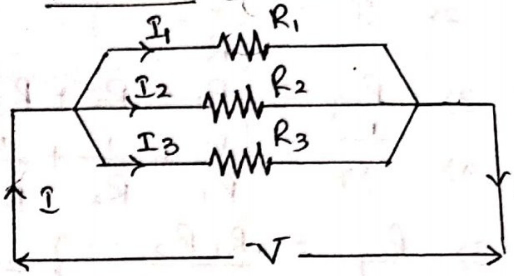
*> The equivalent resistance is always greater than individual resistance.

ie; $R_{eq} > R_1$

$R_{eq} > R_2$

$R_{eq} > R_3$

Parallel circuit



*> The voltage across all the resistor is same.

*> Current through each resistor is different.

*> The total current is the sum of branch currents

ie; $I = I_1 + I_2 + I_3$

*> The reciprocal of equivalent resistance is the sum of resiprocal of individual resistances.

ie; $\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

*> The equivalent resistance is always smaller than individual resistance.

ie; $R_{eq} < R_1$

$R_{eq} < R_2$

$R_{eq} < R_3$

List of formulae

1) $V = IR$ } Ohm's law
2) $I = \frac{V}{R}$ }

3) $R_{eq} = R_1 + R_2 + R_3$ } series circuit

4) $\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$ } ||lel circuit

5) $R_{eq} = \frac{R_1 R_2}{R_1 + R_2}$ } 2-resistors are in ||lel

6) $I_1 = I\left[\frac{R_2}{R_1+R_2}\right]$ } current division Rule.
7) $I_2 = I\left[\frac{R_1}{R_1+R_2}\right]$ } if 2-resistors are connected in ||lel.

8) $I = I_1 + I_2$

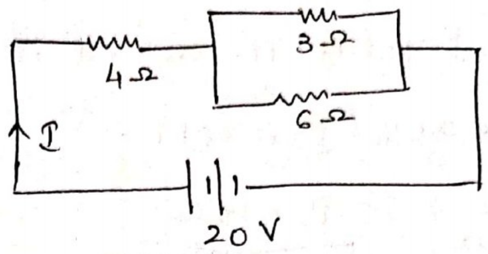
9) $P = V \times I$ } Power equations
10) $P = I^2 R$ }
11) $P = \frac{V^2}{R}$ }

12) $E = P \times t = VI \times t$ joules } Energy equation.

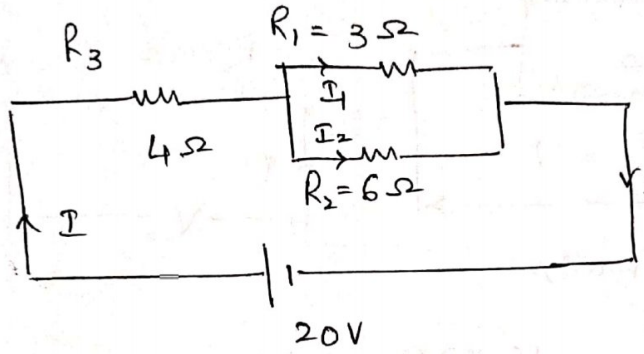
QP solved Numericals of DC Circuits.

(1) from the given below ckt, find the c/r through 6Ω resistor (5m) Dec 2016 | Jan 2017.

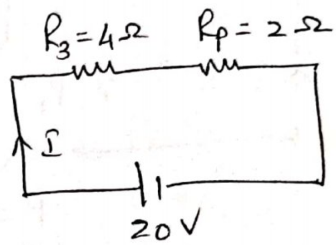
Sol^n:



Sol^n:



$\Rightarrow$



$R_p = \frac{3\times 6}{3+6}$ WKT $R_p = \frac{R_1 R_2}{R_1 + R_2} = \frac{3\times 6}{3+6} = \frac{18}{9}$

$R_p = 2\Omega$

WKT $R_{eq} = R_3 + R_p = 4 + 2 = 6\Omega$

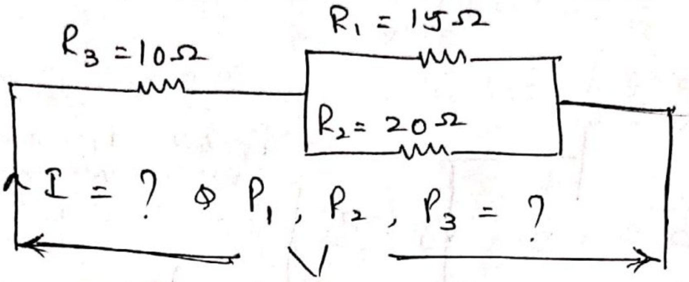
WKT $V = IR \quad \therefore I = \frac{V}{R_{eq}} = \frac{20}{6} = 3.333A$

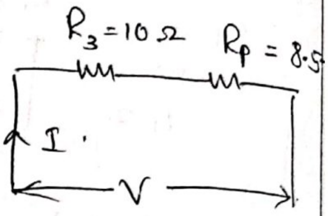
WKT $I_2 = I\left[\frac{R_1}{R_1+R_2}\right] = 3.333\left[\frac{3}{6+3}\right] = \frac{3.333\times 3}{9}$

$\boxed{I_2 = 1.111\ A}$ $\therefore$ the current through 6Ω resistor is 1.111 A.

(2) A $10\,\Omega$ resistance is connected in series with a ||lel combination of $15\,\Omega$ & $20\,\Omega$ resistors. The circuit is applied with V volts. The power taken by the ckt is 150 watts. Find the total current through the circuit and power consumed in all the resistors. (6m) Dec 2016 / Jan 2017.

Sol^n:





$P = 150$ watts

WKT :- $R_p = \dfrac{R_1 \times R_2}{R_1 + R_2} = \dfrac{15 \times 20}{15 + 20} = \dfrac{300}{35} = 8.571\,\Omega$

WKT :- $R_{eq} = R_3 + R_p = 10 + 8.571 = 18.571\,\Omega$

WKT :- $P = I^2 R_{eq}$ $\therefore$ $I^2 = \dfrac{P}{R_{eq}} = \dfrac{150}{18.571} = 8.077$

$\therefore$ $\boxed{I = 2.842\ A}$

WKT $P_1 = I_1^2 R_1$ ~~WKT~~

$I_1 = I \left[\dfrac{R_2}{R_1 + R_2}\right]$

$= 2.842 \left[\dfrac{20}{20+15}\right]$

$I_1 = 1.624\ A$.

WKT :- $I = I_1 + I_2$

& $I_2 = I - I_1$ ~~= 2.842~~

$= 2.842 - 1.624$

$I_2 = 1.218\ A$

$P_1 = (1.624)^2 \times 15$

$\boxed{P_1 = 39.561 \text{ watts}}$

WKT $P_2 = I_2^2 R_2$

$P_2 = (1.218)^2 \times 20$

$\boxed{P_2 = 29.67 \text{ watts}}$

WKT $P_3 = I^2 R_3 = (2.842)^2 \times 10 = \boxed{80.826 \text{ watts}}$

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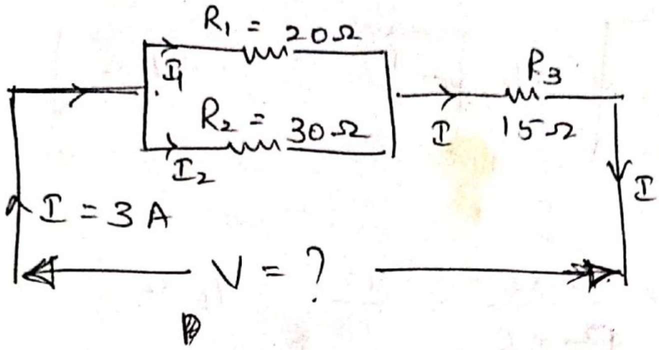
(3) A ckt of two \|\|el resistors having resistance of 20Ω & 30Ω connected in series with 15Ω. If the c/t through 15Ω resistor is 3A. Find i) c/t in 20Ω & 30Ω resistors ii) V/t across the whole ckt iii) The total power and power consumed in all resistors. (5m) Dec 2015/Jan 2016.

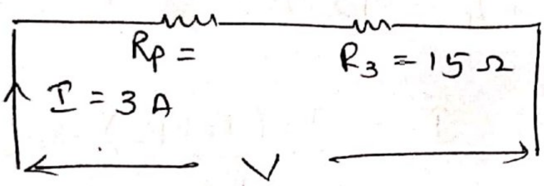
Sol:



Find i) $I_1 = ?$ & $I_2 = ?$
ii) $V = ?$
iii) $P, P_1, P_2 = ?$

WKT $R_p = \dfrac{R_1 R_2}{R_1 + R_2} = \dfrac{20 \times 30}{20+30}$

$R_p = \dfrac{600}{50} = 12\Omega$



WKT !- $R_{eq} = R_p + R_3 = 12 + 15 = 27\Omega$

WKT !- $V = I R_{eq} = 3 \times 27 = 81V$

$\boxed{V = 81V}$ //

WKT !- $I_1 = I\left[\dfrac{R_2}{R_1+R_2}\right] = 3\left[\dfrac{30}{20+30}\right] = 1.8A$

$\boxed{I_1 = 1.8A}$

WKT !- $I_2 = I - I_1 = 3 - 1.8 = 1.2A$

$\boxed{I_2 = 1.2A}$ or $I_2 = I\left[\dfrac{R_1}{R_1+R_2}\right]$

WKT !- $P = VI = 81 \times 3 = 243$ watts

$\boxed{P = 243 \text{ watts}}$

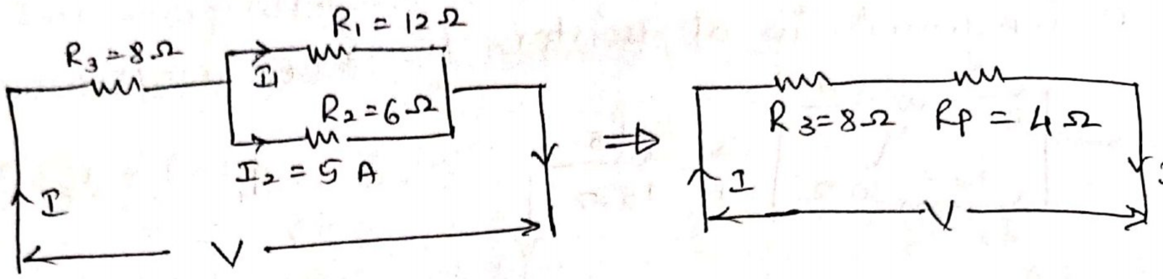
WKT !- $P_1 = I_1^2 R_1 = (1.8)^2 \times 20 = 64.8$ watts //

$P_2 = I_2^2 R_2 = (1.2)^2 \times 30 = 43.2$ watts //

WKT !- $P = P_1 + P_2 + \ldots$ $P_3 = I^2 R_3 = 3^2 \times 15 = 135$ watts //

(4) An 8 Ω resistor is in series with a ||el combination of two resistors 12 Ω and 6 Ω. If the current in 6 Ω resistor is 5 A, determine the total power dissipated in the ckt (6 m) June | July 2016.

Sol:



$P = ?$

WKT :- $R_p = \frac{R_1 \times R_2}{R_1 + R_2} = \frac{12 \times 6}{12 + 6} = \frac{72}{18} = 4\,\Omega$

WKT :- $R_{eq} = R_3 + R_p = 8 + 4 = 12\,\Omega$

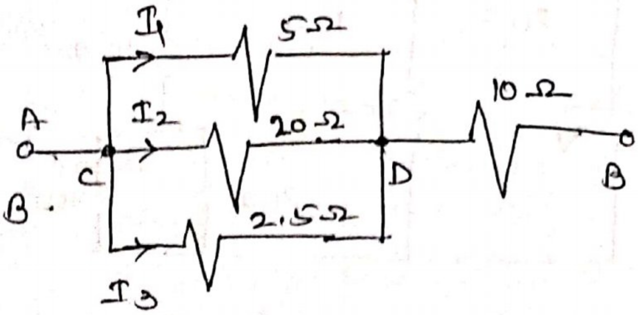
WKT :- $I_2 = I\left[\frac{R_1}{R_1 + R_2}\right]$ ∴ $I = \frac{I_2 (R_1 + R_2)}{R_1}$

∴ $I = \frac{5 \times (12 + 6)}{12} = 7.5\,A$.

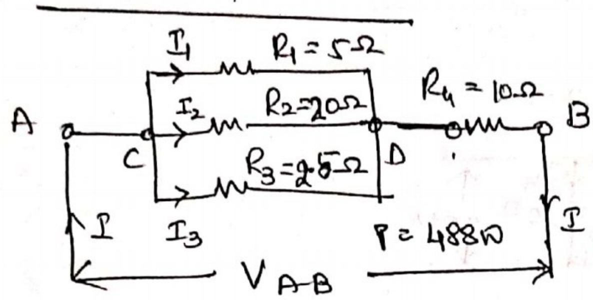
WKT :- $P = I^2 R_{eq} = (7.5)^2 \times 12$

$$\boxed{P = 675 \text{ watts}}$$

(5) For the ckt shown in fig the total power dissipated is 488 W. Calculate the c/t flowing in each resistance & P.D betⁿ A & B. (5m) Dec2015/Jan2016



Solⁿ:



Find

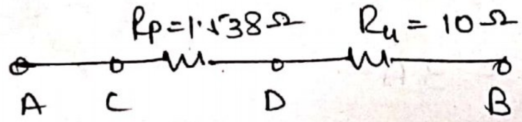
i) $I, I_1, I_2, I_3 = ?$

ii) $V_{AB} = ?$

R_1, R_2 & R_3 are in ||eel.

$$\therefore \frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{5} + \frac{1}{20} + \frac{1}{2.5} = 0.65\Omega$$

$\therefore R_P = 1.538\Omega$



$\therefore R_{eq} = R_P + R_4$ (series)

$\therefore R_{eq} = 1.538 + 10$

$R_{eq} = 11.538\Omega$.

WKT $P = \frac{V_{AB}^2}{R_{eq}}$ $\therefore V_{AB} = \sqrt{P \times R_{eq}} = \sqrt{488 \times 11.538} = 75.03V$

$\therefore \boxed{V_{AB} = 75V}$

WKT:- $I = \frac{V}{R_{eq}} = \frac{75}{11.538} = \boxed{6.5A}$

WKT:- $V_{DB} = IR_4 = 6.5 \times 10 = 65V$.

WKT:- $V_{CD} = V_{AB} - V_{DB} = 75 - 65 = 10V$

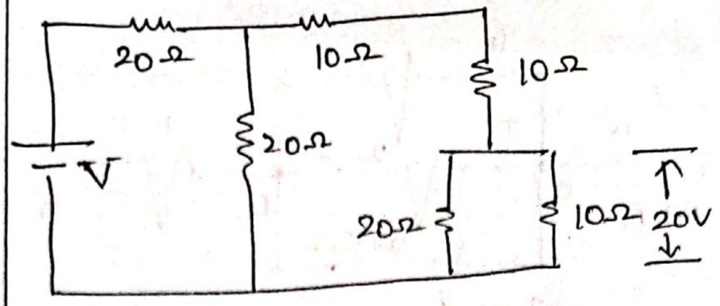
or $V_{CD} = I R_P$
$= 6.5 \times 1.538$
$V_{CD} = 10V$

WKT:- $I_1 = \frac{V_{CD}}{R_1} = \frac{10}{5} = 2A$ //

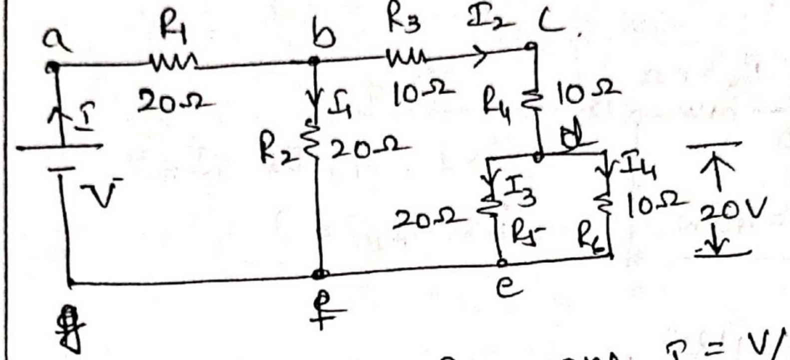
$I_2 = \frac{V_{CD}}{R_2} = \frac{10}{20} = 0.5A$ //

$I_3 = \frac{V_{CD}}{R_3} = \frac{10}{2.5} = 4A$ //

(6) Calculate the supply v/g V in the following ckt. (6M) June/July 2016



Sol:



20V is ||el to R_5 & R_6. WKT $I = V/R$.

$\therefore \; I_3 = \frac{20}{R_5} = \frac{20}{20} = 1\,A$ ie; $I_3 = V_{de}/R_5$

||ly $I_4 = \frac{20}{R_6} = \frac{20}{10} = 2\,A$. & $I_4 = V_{de}/R_6$.

WKT :- $I_2 = I_3 + I_4 = 1 + 2 = 3\,A$.

WKT :- $V_{10\Omega} = I_2 \times R_4 = 3 \times 10 = 30V$.
or (V_{cd})

WKT :- $V_{ce} = V_{cd} + V_{de} = 30 + 20 = 50V$.

WKT :- $V_{bc} = I_2 \times R_3 = 3 \times 10 = 30V$.

WKT :- $V_{bf} = V_{bc} + V_{ce} = 30 + 50 = 80V$

WKT :- $I_1 = \frac{V_{bf}}{R_2} = \frac{80}{20} = 4\,A$.

WKT :- $I = I_1 + I_2 = 3 + 4 = 7\,A$.

WKT :- $V_{ab} = I R_1 = 7 \times 20 = 140\,V$

WKT :- $V = V_{ag} = V_{ab} + V_{bf} = 140 + 80$

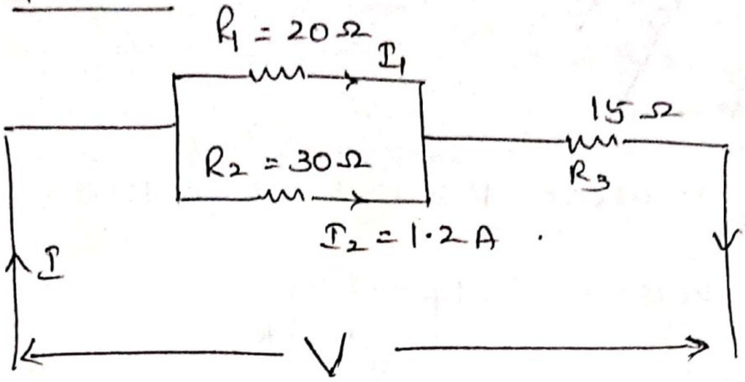
$\boxed{V = 220V}$

(7) A ckt consists of two ||el resistors having resistances of 20Ω & 30Ω respectively, connected in series with 15Ω resistor. If the c/r through 30Ω resistor is 1.2 A. Find i) c/r in 20Ω & 15Ω ii) V/r a/c the whole ckt iii) V/r a/c 15Ω & 20Ω iv) Total power consumed in the ckt.

(8m) Dec 2014 / Jan 2015

Sol^n :-

Given



Find :-

i) $I_1 = ?$ & $I = ?$

ii) $V = ?$

iii) V_{15} & $V_{30} = ?$

iv) $P = ?$

WKT :- $R_{eq} = \frac{R_1 R_2}{R_1 + R_2} + R_3 = \frac{20 \times 30}{20+30} + 15 = 27\Omega$

WKT :- $I_2 = I\left[\frac{R_1}{R_1+R_2}\right]$ $\therefore$ $I = \frac{I_2 (R_1+R_2)}{R_1} = \frac{1.2(50)}{20}$

i) $\boxed{I = 3A}$

WKT :- $I_1 = I - I_2 = 3 - 1.2 = 1.8 A$

$\boxed{I_1 = I_{20\Omega} = 3A}$

WKT :- $V = I R_{eq} = 3 \times 27 = 81V$

ii) $\boxed{V = 81V}$

WKT :- $V_{15\Omega} = I \times R_3 = 3 \times 15 = 45V$

iii) $\boxed{V_{15\Omega} = 45V}$

WKT :- $V_{20\Omega} = I_1 \times R_1 = 1.8 \times 20 = 36V$

$\boxed{V_{20\Omega} = 36V}$

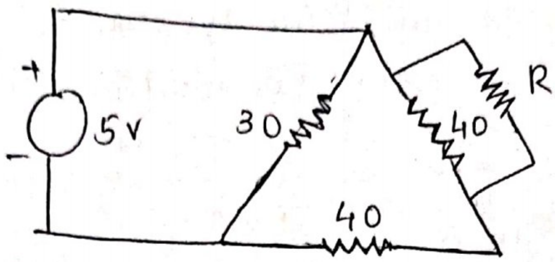
WKT :- $P = VI = 81 \times 3 = 243$ watts

iv) $\boxed{P = 243 \text{ watts}}$

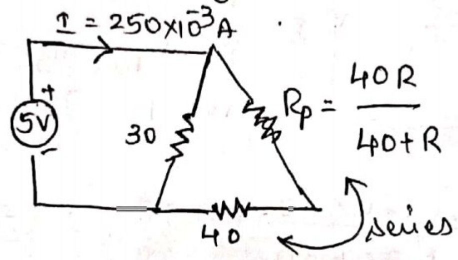
(8) Find the value of resistance 'R' as shown in fig, so that c/t drawn from the source is 250 mA. All the resistor values are in ohms

(6m)

DEC 2013 / JAN 2014

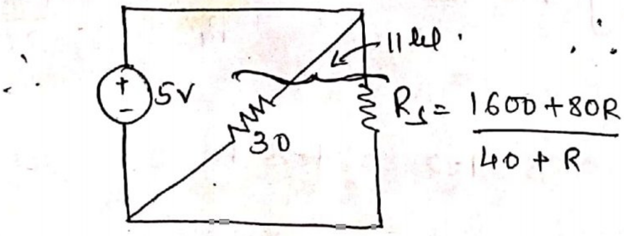


Sol: From the fig shown above R & 40Ω are in ||lel.



$\therefore R_p = \frac{40R}{40+R}$.

Now in the above ckt 40Ω & Rp are in series.



$\therefore R_s = R_p + 40$

$= \frac{40R}{40+R} + 40$

$R_s = \frac{1600+80R}{40+R}$

Now 30Ω & Rs are in ||lel.

$\therefore R_{eq} = \frac{30 \times R_s}{30 + R_s} = \frac{30\left[\frac{1600+80R}{40+R}\right]}{30+\left[\frac{1600+80R}{40+R}\right]}$

$R_{eq} = \frac{\frac{30\times(1600+80R)}{(40+R)}}{\frac{(40+R)30+1600+80R}{(40+R)}} \Rightarrow \frac{48000+2400R}{2800+110R}$

ie; $R_{eq} = \frac{48000+2400R}{2800+110R}$ ——— (1)

W.K.T: $V = I R_{eq}$ $\therefore R_{eq} = \frac{V}{I}$

ie; $R_{eq} = \frac{5}{250\times10^{-3}} = \frac{5000}{250} = 20\,\Omega$

$\therefore$ (1) $\Rightarrow$ $20 = \frac{48000 + 2400R}{2800 + 110R}$

$20(2800+110R) = 48000 + 2400R$

$56000 + 2200R = 48000 + 2400R$

$56000 - 48000 = 2400R - 2200R$

$8000 = 200R$

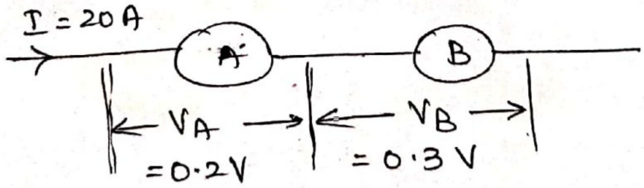
$\therefore R = \frac{8000}{200}$

$$\boxed{R = 40\,\Omega}$$

---

(9) A c/t of 20 A flows through two ammeters A & B in series. The potential difference across A is 0.2V and across B is 0.3V. Find how the same c/t will divide bet^n A & B when they are in ||el.

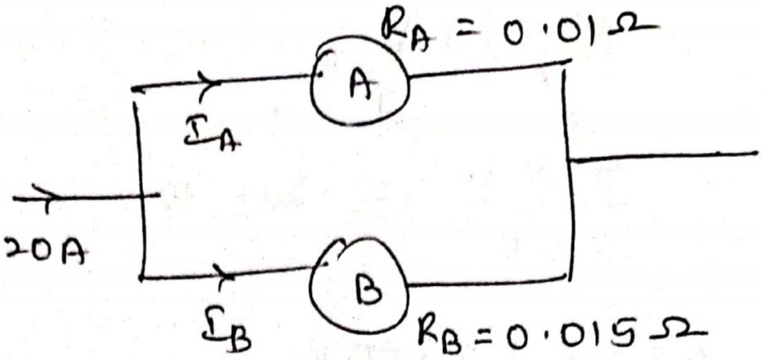
Sol^n: Given: $I = 20A$



W.K.T: $R_A = \frac{V_A}{I_A} = \frac{0.2}{20} = 0.01\,\Omega$

$R_B = \frac{V_B}{I_B} = \frac{0.3}{20} = 0.015\,\Omega$

Now A & B ammeters are connected in ||el.



W.K.T :- $I_A = I\left[\dfrac{R_B}{R_A + R_B}\right] = 20\left[\dfrac{0.015}{0.01+0.015}\right]$

∴ $\boxed{I_A = 12\ A}$

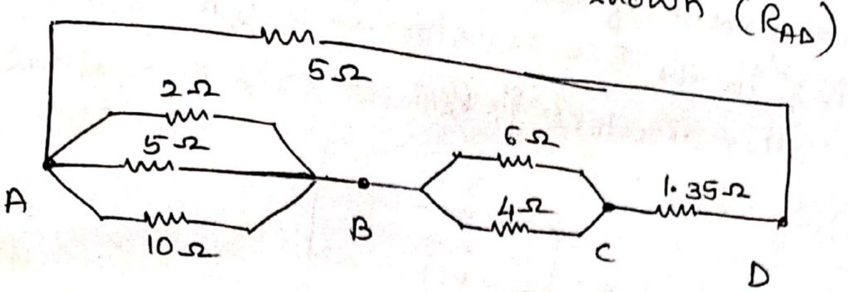
W.K.T :- $I_B = I - I_A = 20 - 12 = \cancel{1}8\ A$

∴ $\boxed{I_B = \cancel{1}8\ A}$

∴ When the two Ammeters A & B are connected in ||el the two c/s are.

$I_A = 12\ A$ & $I_B = 18\ A$

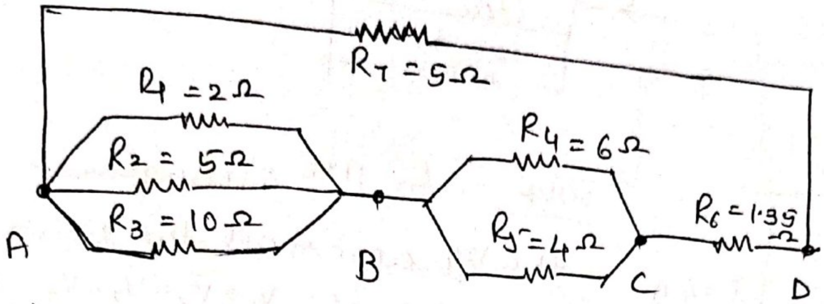
Find the resistance of the ckt shown (R_{AD})



(5m)

June/July 2013

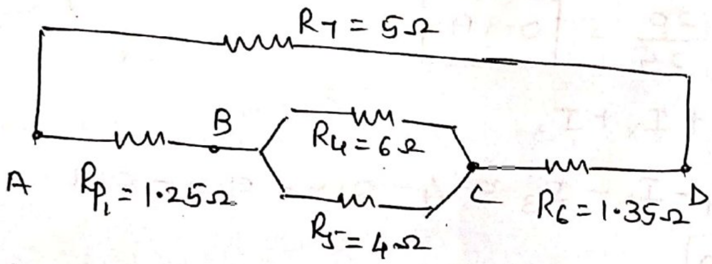
Sol :-



Step 1 :- R_1, R_2 & R_3 are in ||lel.

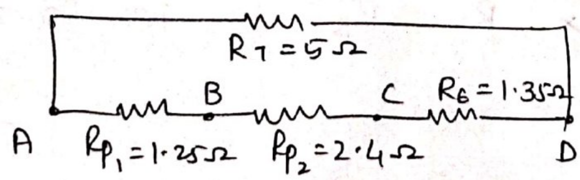
$$\therefore \frac{1}{R_{P_1}} = \frac{1}{2} + \frac{1}{5} + \frac{1}{10} = \frac{8}{10}$$

$$\therefore R_{P_1} = \frac{10}{8} = 1.25\Omega$$



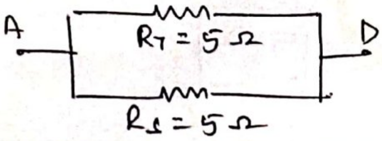
Step 2 :- R_4 & R_5 are in ||lel

$$\therefore R_{P_2} = \frac{R_4 R_5}{R_4 + R_5} = \frac{6 \times 4}{6+4} = \frac{24}{10} = 2.4\Omega$$



Step 3 :- R_{P_1}, R_{P_2} & R_6 are in series.

$$\therefore R_S = R_{P_1} + R_{P_2} + R_6 = 1.25 + 2.4 + 1.35 = 5\Omega$$



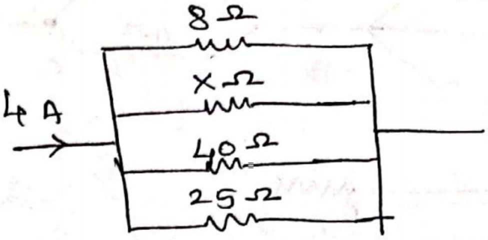
Step 4 :- R_7 & R_S are in ||lel

$$\therefore R_{AD} = R_{eq} = \frac{R_7 \times R_S}{R_7 + R_S} = \frac{5 \times 5}{5+5} = 2.5\Omega$$

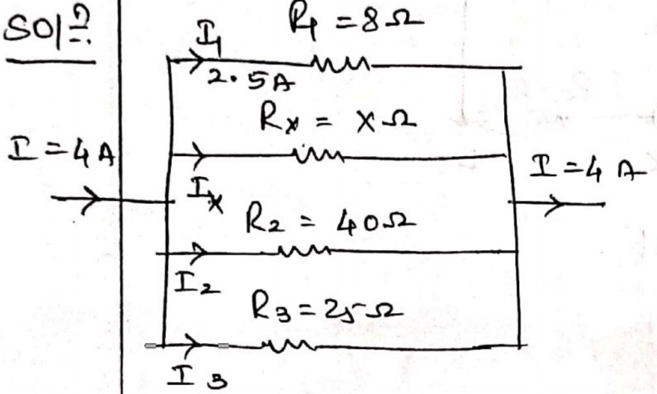
$$\therefore \boxed{R_{AD} = 2.5\Omega}$$

(11) In the ||^{el} arrangement of resistors shown in the fig the c/t flowing in the 8Ω resistor is 2·5 A Find i) Current in other resistors ii) Resistor x iii) The equivalent resistance.

(6m) June/July 2013



Sol^n:



WKT :- In ||^{el} arrangement the V/t across all the resistor is same ie; $V_1 = V_x = V_2 = V_3 = V$

$\therefore V_1 = I_1 R_1 = 8 \times 2{\cdot}5 = 20V$

$\therefore V = 20V$

WKT :- $I_2 = \frac{V}{R_2} = \frac{20}{40} = \boxed{0{\cdot}5 \text{ A}}$

WKT :- $I_3 = \frac{V}{R_3} = \frac{20}{25} = \boxed{0{\cdot}8 \text{ A}}$

WKT :- $I = I_1 + I_2 + I_x + I_3$

$\therefore I_x = I - I_1 - I_2 - I_3 = 4 - 2{\cdot}5 - 0{\cdot}5 - 0{\cdot}8$

$\boxed{I_x = 0{\cdot}2 \text{ A}}$

WKT :- $R_x = \frac{V}{I_x} = \frac{20}{0{\cdot}2} = \boxed{100\Omega}$

WKT :- $\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_x} + \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{8} + \frac{1}{100} + \frac{1}{40} + \frac{1}{25}$

$\frac{1}{R_{eq}} = 0{\cdot}2$

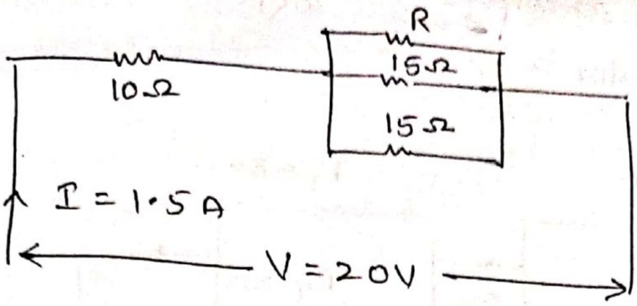
$\boxed{R_{eq} = 5\Omega}$

Or WKT :- $V = I R_{eq}$

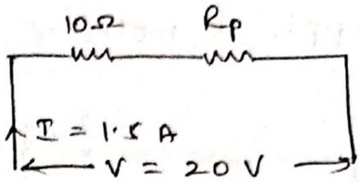
$\therefore R_{eq} = \frac{V}{I} = \frac{20}{4} = \boxed{5\Omega}$ //

12) A resistance of 10Ω is connected in series with the two resistances each of 15Ω arranged in parallel. What resistance must be shunted across this ||el combination so that total current taken will be 1.5A from 20V supply.

Sol^n:-



⇒



WKT :- $\frac{1}{R_p} = \frac{1}{R} + \frac{1}{15} + \frac{1}{15} = \frac{15+2R}{15R}$

$\therefore R_p = \frac{15R}{15+2R}$

WKT :- $R_{eq} = 10 + R_p = 10 + \frac{15R}{15+2R} = \frac{10(15+2R)+15R}{15+2R}$

$R_{eq} = \frac{150+35R}{15+2R}$ —— (1)

WKT :- $R_{eq} = \frac{V}{I} = \frac{20}{1.5} = 13.33\,\Omega$ —— (2)

Substitute (2) in (1)

$\therefore$ (1) ⇒ $13.33 = \frac{150+35R}{15+2R}$

$13.33(15+2R) = 150 + 35R$

$199.95 + 26.66R = 150 + 35R$

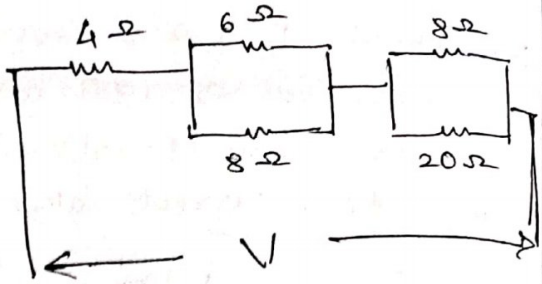
$199.95 - 150 = 35R - 26.66R$

$49.95 = 8.34R$

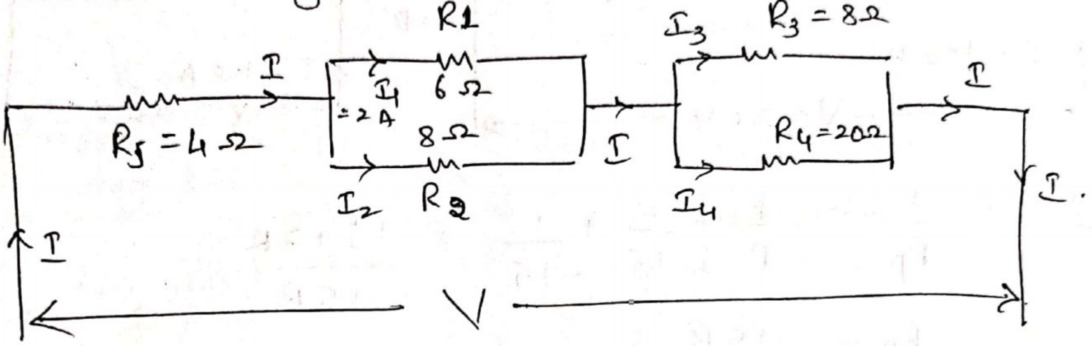
$\therefore R = \frac{49.95}{8.34} = 5.989\,\Omega \approx 6\,\Omega$

$$\boxed{R = 6\,\Omega}$$

(13) The current in the 6 Ω resistance of the network shown in the fig is 2A. Determine the c/t-s in all the branches & the applied voltage



Sol^n:



WKT :- $R_{eq} = R_5 + \frac{R_1 R_2}{R_1 + R_2} + \frac{R_3 R_4}{R_3 + R_4} = 4 + \frac{6 \times 8}{6+8} + \frac{8 \times 20}{8+20}$

$R_{eq} = 4 + 3.428 + 5.7142 = 13.142\,\Omega$

WKT :- $I_1 = I\left[\frac{R_2}{R_1+R_2}\right]$

$\therefore I = I_1\left[\frac{R_1+R_2}{R_2}\right] = 2\left[\frac{8+6}{8}\right]$

$$\boxed{I = 3.5A}$$

WKT :- $I_2 = I - I_1 = 3.5 - 2$

$$\boxed{I_2 = 1.5A}$$

WKT :- $I_3 = I\left[\frac{R_4}{R_3+R_4}\right]$

$= 3.5\left[\frac{20}{8+20}\right]$

$$\boxed{I_3 = 2.5A}$$

WKT :- $I_4 = I - I_3 = 3.5 - 2.5$

$$\boxed{I_4 = 1A}$$

WKT :- $V = I R_{eq}$

$\therefore V = 3.5 \times 13.142$

$V = 45.997$ volts

$$\boxed{V = 46V}$$

$\therefore$ the c/t in all the brances is

$I = 3.5A$, $I_1 = 2A$,

$I_2 = 1.5A$, $I_3 = 2.5A$

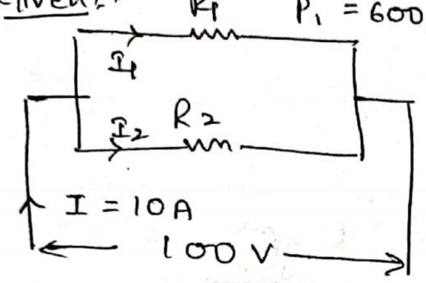
& $I_4 = 1A$.

& the applied voltage

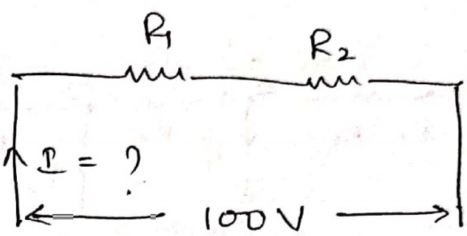
$V = 46V$

(14) Two resistors connected in ||el across 100V D.C supply. The total current from the supply source is 10 A. The power dissipated in one resistor is 600W. What is the ckt drawn when they are connected in series across the same supply. (8m) DEC 2017 | Jan 2018.

Sol^n:- Given:-



Find



WKT:- $P = V^2/R$

$\therefore \quad R_1 = \dfrac{V^2}{P_1} = \dfrac{(100)^2}{600}$

$R_1 = 16.6667\Omega$

WKT:- $I_1 = \dfrac{V}{R_1} = \dfrac{100}{16.667}$

$I_1 = 6A$

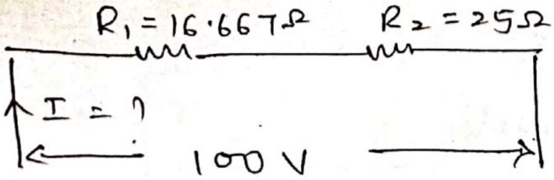
WKT:- $I_2 = I - I_1 = 10 - 6$

$I_2 = 4A$

WKT:- $R_2 = \dfrac{V}{I_2} = \dfrac{100}{4}$

$R_2 = 25\Omega$

$\therefore$ When the two resistors are connected in series the ckt will be.



WKT

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

$= 16.6667 + 25$

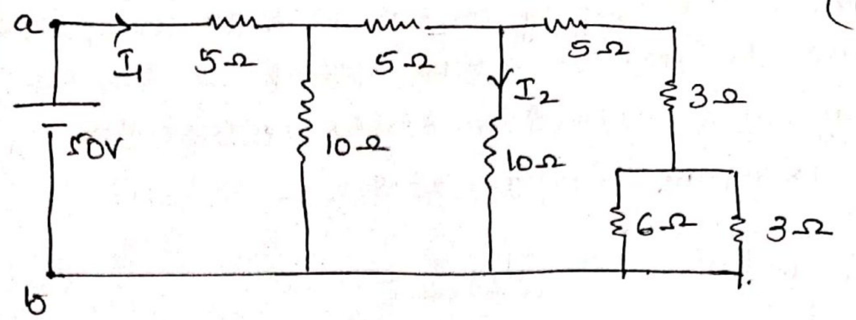
$R_{eq} = 41.6667\Omega$

WKT $I = \dfrac{V}{R_{eq}} = \dfrac{100}{41.6667}$

$\therefore \boxed{I = 2.4A}$

(15). Refer fig & find I_1, I_2 and the power in the 6Ω resistor (7m)

DEC 2017 / Jan 2018



Sol^n :-

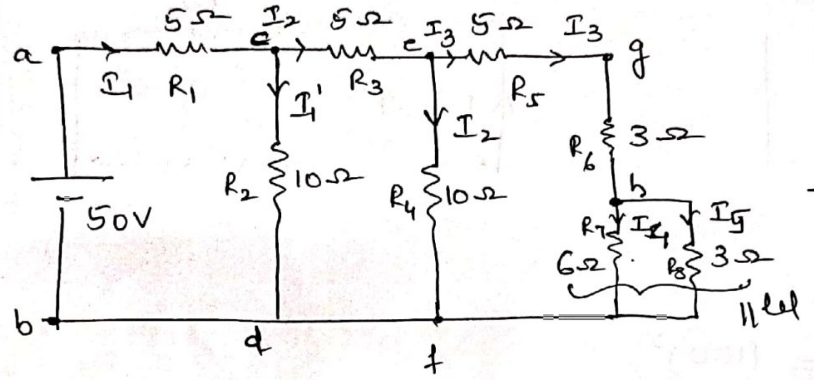
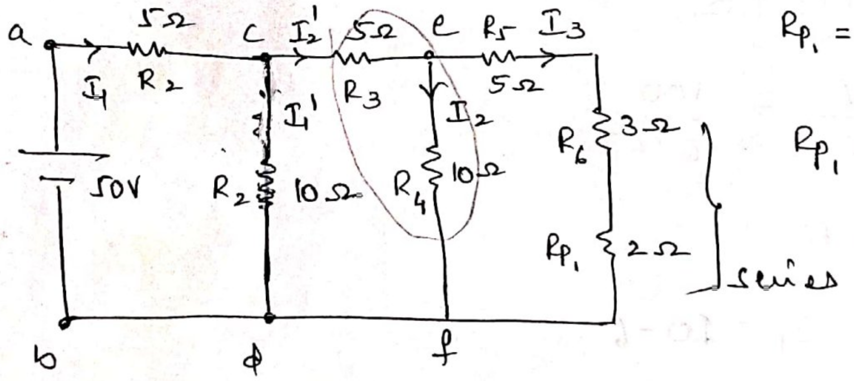


fig ①

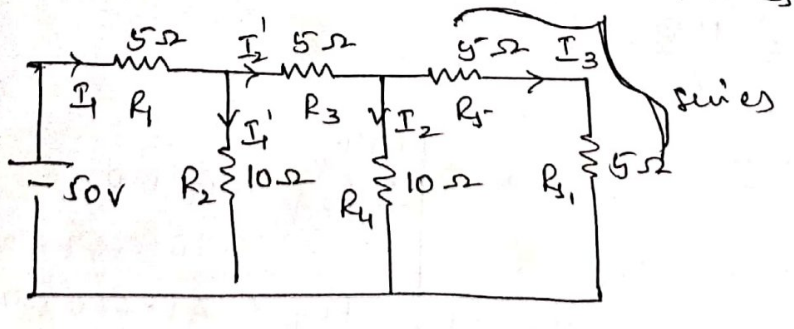
Step 1 :- 3Ω & 6Ω resistors are in ||el



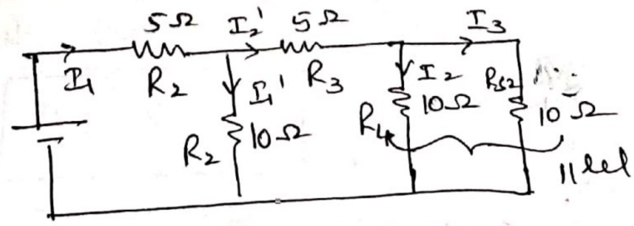
$$R_{p_1} = \frac{6\times 3}{6+3} = \frac{18}{9}$$

$$R_{p_1} = 2\Omega$$

Step 2 :- 3Ω & 2Ω are in series $\therefore R_{s_1} = 3 + 2 = 5\Omega$

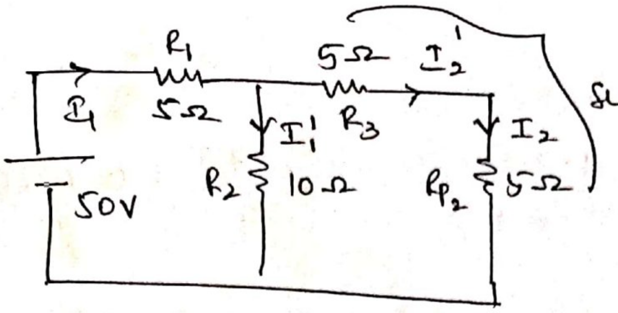


Step 3 :- 5Ω & 5Ω are in series $\therefore R_{s_2} = 5 + 5 = 10\Omega$

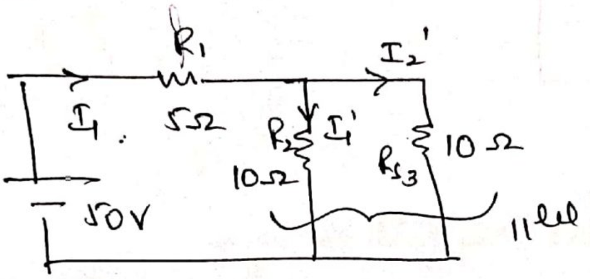


Step 4 :- 10 Ω & 10 Ω are in ||lel. $\therefore R_{p_2} = \frac{10 \times 10}{10 + 10}$

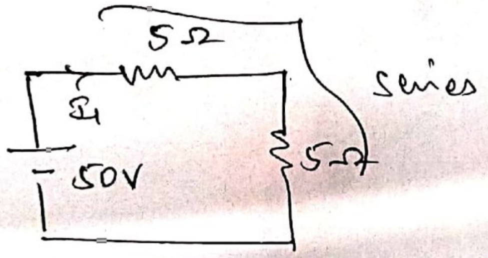
$R_{p_2} = 5\,\Omega$.



Step 5 :- 5 Ω & 5 Ω are in series $\therefore R_{s_3} = 5 + 5 = 10\,\Omega$



Step 6 :- 10 Ω & 10 Ω are in ||lel $\therefore R_{p_3} = \frac{10 \times 10}{10 + 10} = 5\,\Omega$



Step 7 :- 5 Ω & 5 Ω are in series

$\therefore R_{eq} = 5 + 5 = 10\,\Omega$.

WKT :- $I_1 = I = \frac{V}{R_{eq}} = \frac{50}{10} = \boxed{5\,A}$

referring to step 5 fig.

WKT $I_2' = I_1 \left[\frac{R_2}{R_{s_3} + R_2} \right] = 5 \left[\frac{10}{10 + 10} \right] = 2.5\,A$.

referring to step 3 fig.

WKT $I_2 = I_2' \left[\frac{R_{s_2}}{R_4 + R_{s_2}} \right] = 2.5 \left[\frac{10}{10 + 10} \right] = 1.25\,A$

$\therefore \boxed{I_2 = 1.25\,A}$

WKT :- $I_3 = I_2' - I_2 = 2.5 - 1.25 = 1.25A$ ∴

WKT :- from fig (1)

$$I_4 = I_3\left[\frac{R_8}{R_7+R_8}\right] = \frac{1.25\times 3}{6+3} = \frac{3.75}{9} = 0.4166A$$

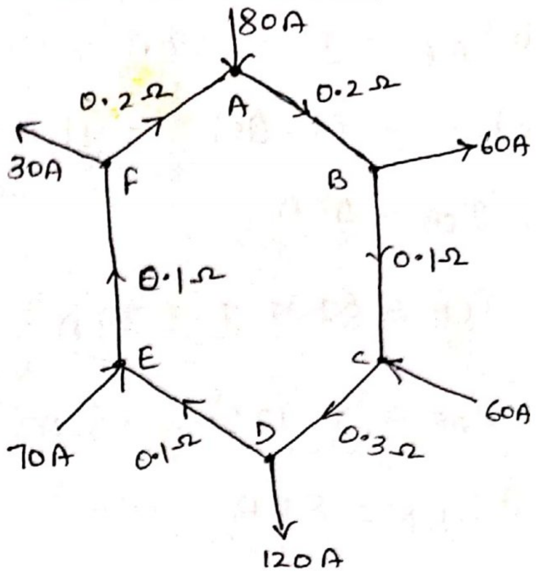
WKT :- $P_{6\Omega} = I_4^2 R_7 = (0.4166)^2 \times 6 = 0.129W$

$$\boxed{P_{6\Omega} = 0.129\,W}$$

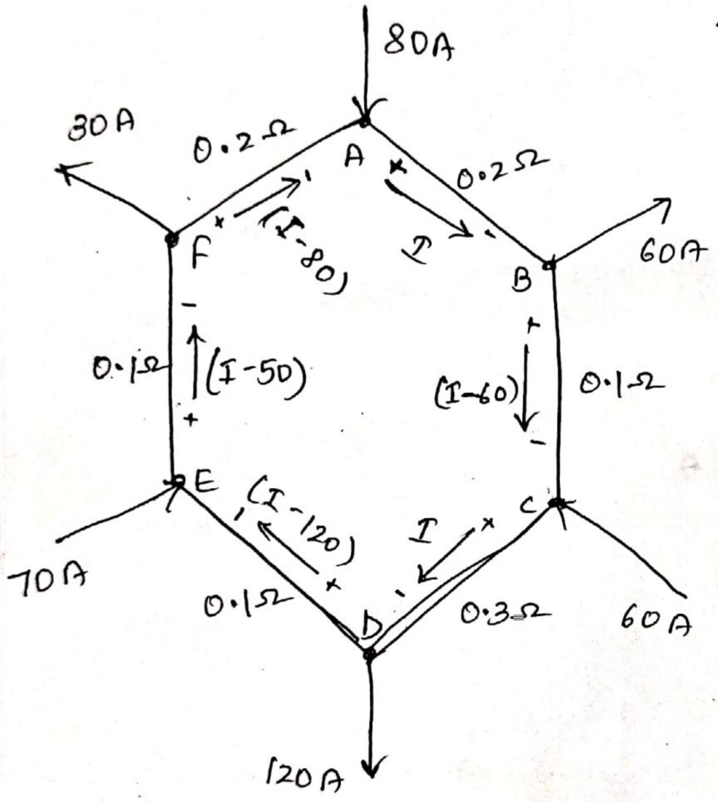
QP solved Numericals on KCL & KVL (DC ckts)

Q1) Find the values of currents in all the branches of the n/w shown in fig

(6m) DEC 2014 | JAN 2015



Sol:



In loop ABCDEFA

$$-0.2I - 0.1(I-60) - 0.3I - 0.1(I-120) - 0.1(I-50) - 0.2(I-80) = 0$$

$$-0.2I - 0.1I + 6 - 0.3I - 0.1I + 12 - 0.1I + 5 - 0.2I + 16 = 0$$

$$-I + 39 = 0$$

$$\therefore \boxed{I = 39\ A}$$

Scanned with CamScanner

∴ Branch C/r-s are

*) $I_{AB} = I = 39\,A$

*) $I_{BC} = (I-60) = -21\,A$

∴ $I_{CB} = 21\,A$

*) $I_{CD} = I = 39\,A$

*) $I_{DE} = (I-120) = -81\,A$

∴ $I_{ED} = 81\,A$

*) $I_{EF} = (I-50) = -11\,A$

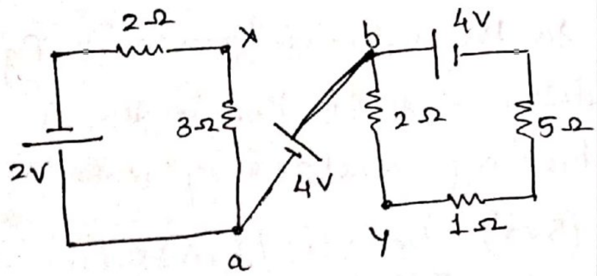
∴ $I_{FE} = 11\,A$

*) $I_{FA} = (I-80) = -41\,A$

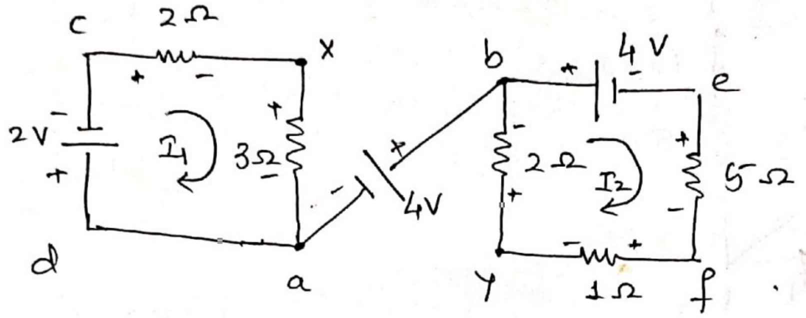
∴ $I_{AF} = 41\,A$.

② For the ckt shown in fig obtain v/t bet^n. the pts X & Y

(6m) June/July 2017



Sol^n:-



loop cxadc

$-2I_1 - 3I_1 - 2 = 0$

$-5I_1 = 2$

$I_1 = -2/5$

$\boxed{I_1 = -0.4A}$

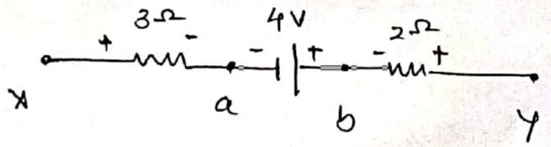
loop befYb

$-4 - 5I_2 - I_2 - 2I_2 = 0$

$-8I_2 = 4$

$I_2 = -4/8$

$\boxed{I_2 = -0.5A}$



$V_{xy} = V_{xa} + V_{ab} + V_{by}$

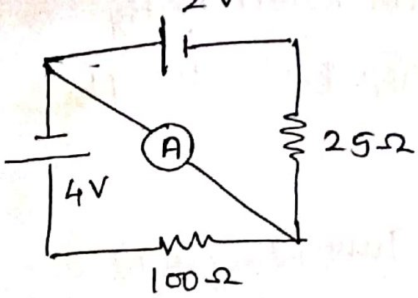
$= -3I_1 + 4 + 2I_2$

$= -3\times(-0.4) + 4 + 2(-0.5)$

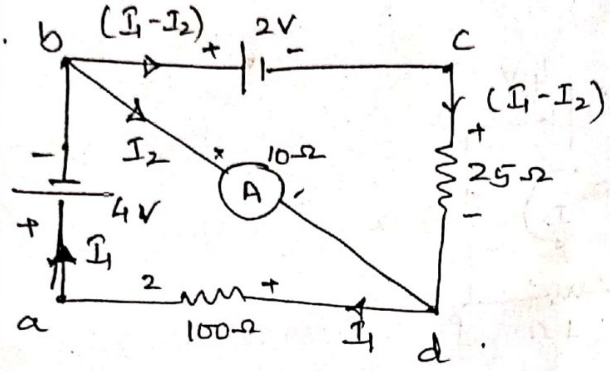
$= 1.2 + 4 - 1$

$\boxed{V_{xy} = 4.2 \text{ Volts}}$ with X +ve.

Q③ In the network shown in fig determine c/t flow in the 'A' having resistance of 10Ω.
(5m) Dec2015/Jan 2016



Sol^{n}:



loop abda

$$-4 - 10I_2 - 100I_1 = 0$$

$$100I_1 + 10I_2 = -4 \quad \text{— (1)}$$

loop bcdb

$$-2 - 25(I_1 - I_2) + 10I_2 = 0$$

$$-25I_1 + 35I_2 = 2 \quad \text{— (2)}$$

solve eq^{n} (1) & (2)

$$100I_1 + 10I_2 = -4 \times 25$$

$$-25I_1 + 35I_2 = 2 \times 100$$

$$25 \times \cancel{100}I_1 + 250I_2 = -100$$

$$-25 \times \cancel{100}I_1 + 3500I_2 = 200$$

$$3750 I_2 = 100$$

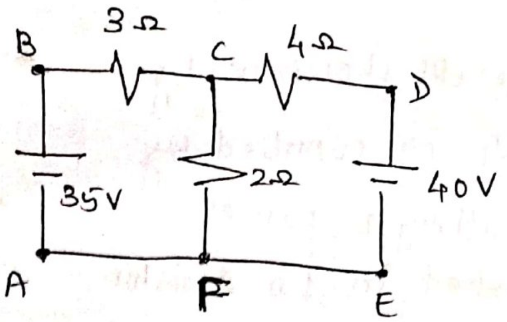
$$I_2 = \frac{100}{3750}$$

$$\therefore \boxed{I_2 = 0.02666\,A}$$

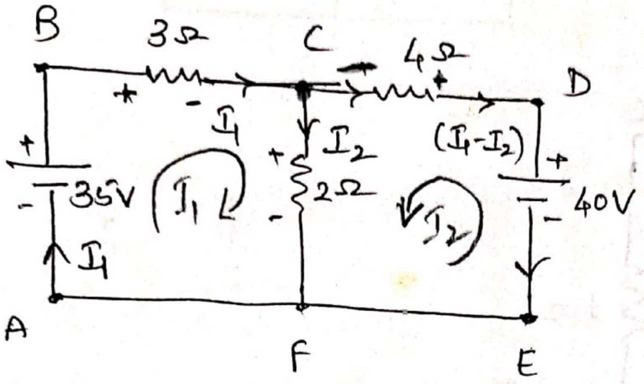
∴ the c/t flowing through milliammeter is $I_2 = 0.02666$ A and the direction is from b to d.

④ For the fig. calculate the c/t in 2Ω resistor

(6m) Dec2015/Jan2016



Sol :-



$$\Sigma E + \Sigma IR = 0$$

$$\Sigma I = 0$$

Loop ABCFA

$$35 - 3I_1 - 2I_2 = 0$$

$$3I_1 + 2I_2 = 35 \quad \text{— (1)}$$

loop CDEFC

$$-4(I_1 - I_2) - 40 + 2I_2 = 0$$

$$-4I_1 + 4I_2 + 2I_2 = 40$$

$$-2I_1 + 3I_2 = 20 \quad \text{— (2)}$$

Solve (1) & (2)

$$3I_1 + 2I_2 = 35 \times 2$$

$$-2I_1 + 3I_2 = 20 \times 3$$

$$\cancel{6I_1} + 4I_2 = 70$$

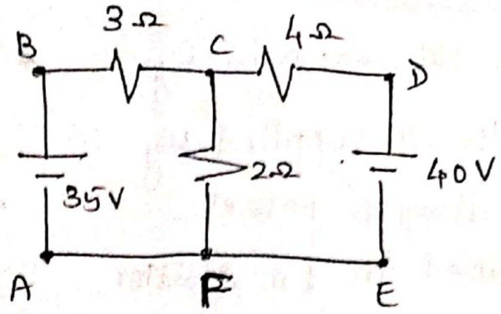
$$-\cancel{6I_1} + 9I_2 = 60$$

$$13I_2 = 130$$

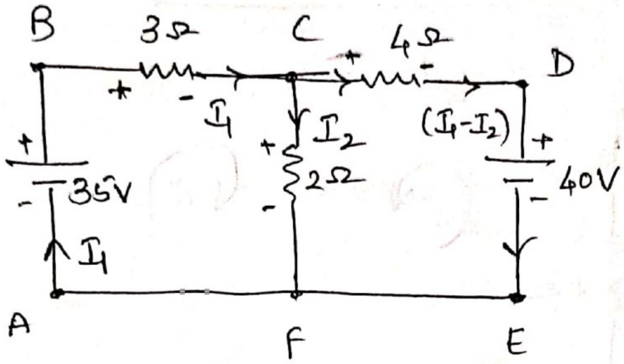
$$\boxed{I_2 = 10\ A}$$

∴ the c/t in 2Ω resistor is 10 A.

4) For the fig. Calculate the c/t in 2Ω resistor (6m) Dec2015 | Jan2016



Sol:



<u>loop ABCFA</u>

$$35 - 3I_1 - 2I_2 = 0$$

$$3I_1 + 2I_2 = 35 \quad \text{--- (1)}$$

<u>loop CDEFC</u>

$$-4(I_1 - I_2) - 40 + 2I_2 = 0$$

$$-4I_1 + 4I_2 + 2I_2 = 40$$

$$-2I_1 + 3I_2 = 20 \quad \text{--- (2)}$$

<u>solve (1) & (2)</u>

$$3I_1 + 2I_2 = 35 \times 2$$

$$-2I_1 + 3I_2 = 20 \times 3$$

$$\cancel{6I_1} + 4I_2 = 70$$

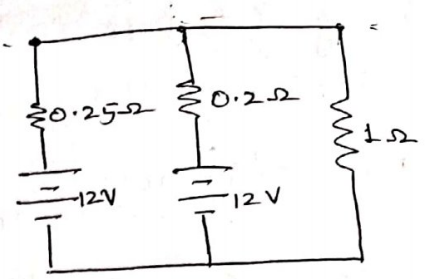
$$-\cancel{6I_1} + 9I_2 = 60$$

$$13 I_2 = 130$$

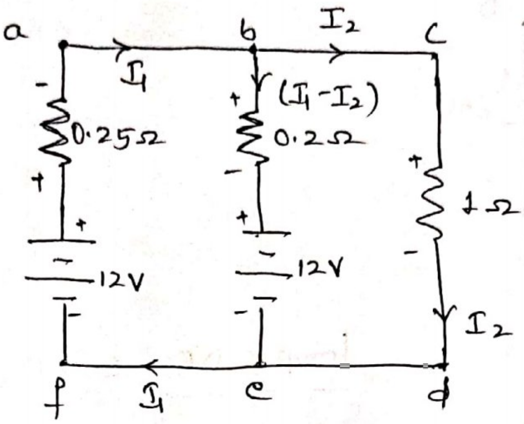
$$\boxed{I_2 = 10\ A}$$

∴ the c/t in 2Ω resistor is 10 A.

Q (5) for the ckt shown in fig find the c/t supplied by each battery & power dissipated in 1Ω resistor



Sol^n:



loop abefa

$-0.2(I_1-I_2) - \cancel{12} + \cancel{12} - 0.25 I_1 = 0$

$-0.2 I_1 + 0.2 I_2 - 0.25 I_1$

$-0.45 I_1 + 0.2 I_2 = 0$ —— (1)

loop bcdeb

$-I_2 + 12 + 0.2(I_1 - I_2) = 0$

$-I_2 + 0.2 I_1 - 0.2 I_2 = -12$

$0.2 I_1 - 1.2 I_2 = -12$ —— (2)

Solve eq^n (1) & (2)

$-0.45 I_1 + 0.2 I_2 = 0 \quad \times 0.2$

$+0.2 I_1 - 1.2 I_2 = -12 \times 0.45$

$-0.2 \times \cancel{0.45} I_1 + 0.04 I_2 = 0$

$+0.2 \times \cancel{0.45} I_1 - 0.54 I_2 = -5.4$

$-0.5 I_2 = -5.4$

$\therefore \boxed{I_2 = 10.8A}$

Substitute $I_2 = 10.8\,A$ in eq$^{\underline{n}}$ 1

1 $\Rightarrow$ $-0.45\, I_1 = -0.2 \times 10.8$

$$I_1 = \frac{2.16}{0.45}$$

$$\boxed{I_1 = 4.8\,A}$$

$\therefore$ c/t supplied by the battery is

$I_1 = 4.8\,A$.

$(I_1 - I_2) = (4.8 - 10.8) = -6\,A$.

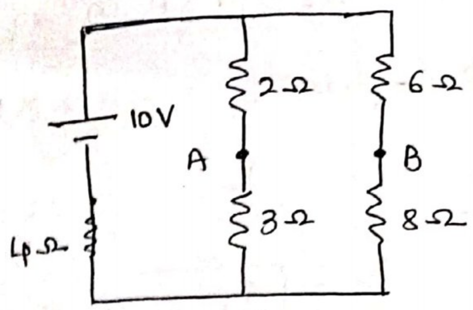
Power dissipated in 1Ω resistor is

$P_{1\Omega} = I_2^2 \times R_{1\Omega} = (10.8)^2 \times 1$

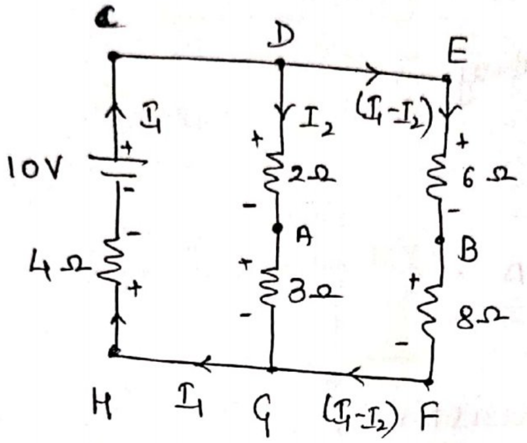
$$\boxed{P_{1\Omega} = 116.64 \text{ watts}}$$

Q⑥ Find the c/t in the battery, the c/t in each branch & P.d across AB in the n/w shown in fig.

(6m) June 2012



Sol^n:



Loop CDGHC.

$$-2I_2 - 3I_2 - 4I_1 + 10 = 0$$

$$-4I_1 - 5I_2 = -10$$

$$4I_1 + 5I_2 = 10 \quad \text{--- (1)}$$

Loop DEFGD

$$-6(I_1 - I_2) - 8(I_1 - I_2) + 3I_2 + 2I_2 =$$

$$-6I_1 + 6I_2 - 8I_1 + 8I_2 + 3I_2 + 2I_2 = 0$$

$$-14I_1 + 19I_2 = 0 \quad \text{--- (2)}$$

solve eq^n (1) & (2).

$$4I_1 + 5I_2 = 10 \times 14$$

$$-14I_1 + 19I_2 = 0 \times 4$$

$$\cancel{14 \times 4} I_1 + 70I_2 = 140$$

$$\cancel{-14 \times 4} I_1 + 76I_2 = 0$$

$$146I_2 = 140$$

$$I_2 = \frac{140}{146}$$

$$\boxed{I_2 = 0.958\,A}$$

Substituting I_2 in eq (2)

(2) $\Rightarrow$ $-14 I_1 = -19 \times 0.958$

$I_1 = 18.219/14$

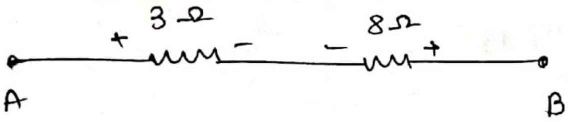
$\boxed{I_1 = 1.3\ A}$

$\therefore$ * C/t in the battery is $I_1 = 1.3\ A$

* C/t in each branch is $I_1 = 1.3\ A$, $I_2 = 0.958\ A$

& $(I_1 - I_2) = (1.3 - 0.958) = 0.342\ A$.

& P.D across AB is



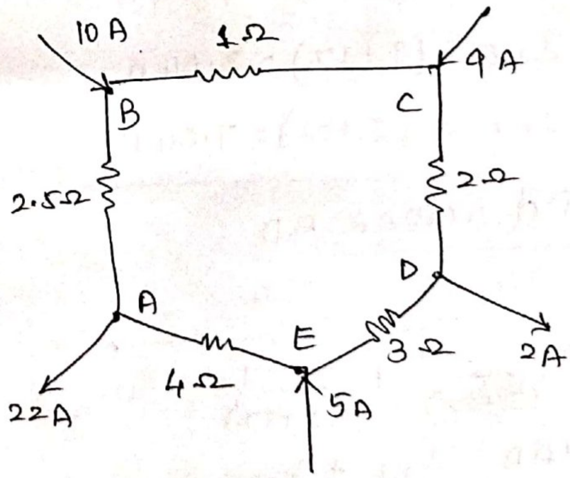
$\therefore V_{AB} = -3 I_2 + 8(I_1 - I_2)$

$= -3 \times 0.958 + 8 \times 0.342$

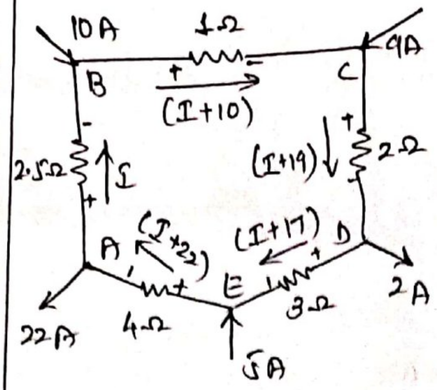
$= -2.874 + 2.736$

$\boxed{V_{AB} = -0.138\ V}$ with B +ve.

Q7) For the n/w shown in Fig find the c/ts in all the branches and p.d across AD & CE.



Sol:-



loop ABCDEA

$$-2.5I-(I+10)-2(I+19)-3(I+17)-4(I+22)=0$$

$$-2.5I-I-10-2I-38-3I-51-4I-88=0$$

$$-12.5I=187$$

$$I=-14.96\,A$$

Branch c/ts

$I_{AB}=I=-14.96\,A$

$I_{BA}=14.96\,A$

$I_{BC}=(I+10)=-4.96\,A$

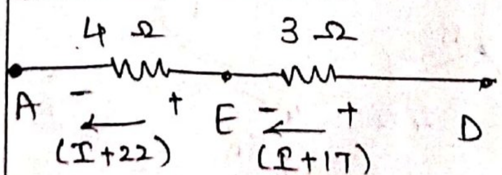
$\therefore I_{CB}=4.96\,A$

$I_{CD}=(I+19)=4.04\,A$

$I_{DE}=(I+17)=2.04\,A$

$I_{EA}=(I+22)=7.04\,A$

Pd across AD



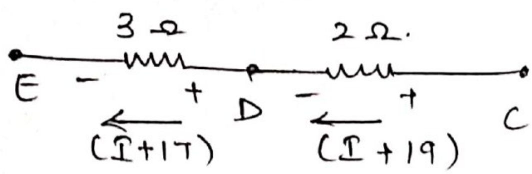
$V_{AD}=V_{AE}+V_{ED}$

$=4\times(I+22)+3\times(I+17)$

$V_{AD}=4\times7.04+3\times2.04$

$\boxed{V_{AD}=34.28\,V}$ w.r.t the ~~D~~ +ve.

Pd across CE



$V_{CE}=V_{CD}+V_{DE}$

$=-2(I+19)-3(I+17)$

$=-2\times4.04-3\times2.04$

$\boxed{V_{CE}=-14.2\,V}$ w.r.t the CE, -ve.

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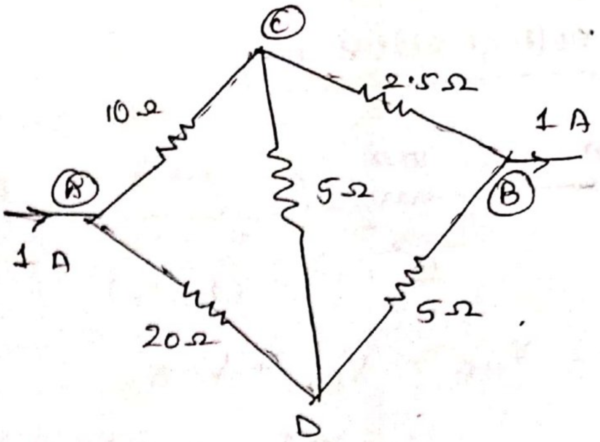
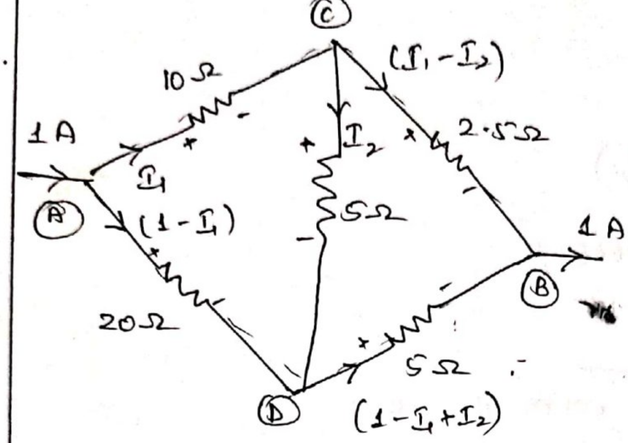
Q8) Find the c/t in all the resistors of the n/w shown in fig. Also Find the v/t across AB



Sol:-



Loop ACDA

$$-10I_1 - 5I_2 + 20(1-I_1) = 0$$
$$-10I_1 - 5I_2 + 20 - 20I_1 = 0$$
$$-30I_1 - 5I_2 = -20$$
$$6I_1 + I_2 = 4 \quad \text{--- (1)}$$

Loop CBDC

$$-2.5(I_1 - I_2) + 5(1 - I_1 + I_2) + 5I_2 = 0$$
$$-2.5I_1 + 2.5I_2 + 5 - 5I_1 + 5I_2 + 5I_2 = 0$$
$$-7.5I_1 + 12.5I_2 = -5$$
$$1.5I_1 - 2.5I_2 = 1 \quad \text{--- (2)}$$

Solve eq^n (1) & (2)

$$6I_1 + I_2 = 4 \quad \times 2.5$$
$$1.5I_1 - 2.5I_2 = 1$$

$$15I_1 + \cancel{2.5I_2} = 10$$
$$1.5I_1 - \cancel{2.5I_2} = 1$$

$$16.5I_1 = 11$$
$$\boxed{I_1 = 0.666\text{ A}}$$

(1) ⇒ $I_2 = 4 - 6 \times 0.666$
$$\boxed{I_2 = 0}$$

C/t in all the branches

$I_{AC} = I_1 = 0.666$ A

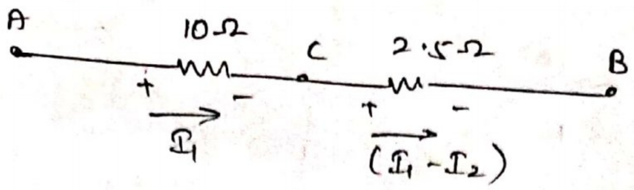
$I_{CD} = I_2 = 0$ A

$I_{AD} = (1 - I_1) = 0.334$ A

$I_{CB} = (I_1 - I_2) = 0.666$ A

$I_{DB} = (1 - I_1 + I_2) = 0.334$ A

Voltage across AB



$$\therefore V_{AB} = V_{AC} + V_{CB}$$

$$= -10 I_1 - 2.5(I_1 - I_2)$$

$$= -10 \times 0.666 - 2.5 \times 0.666$$

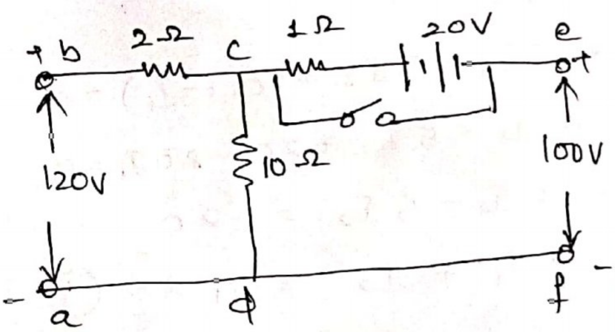
$$= -6.666 - 1.666$$

$$\boxed{V_{AB} = -8.333 \text{ volts}}$$ with B −ve.

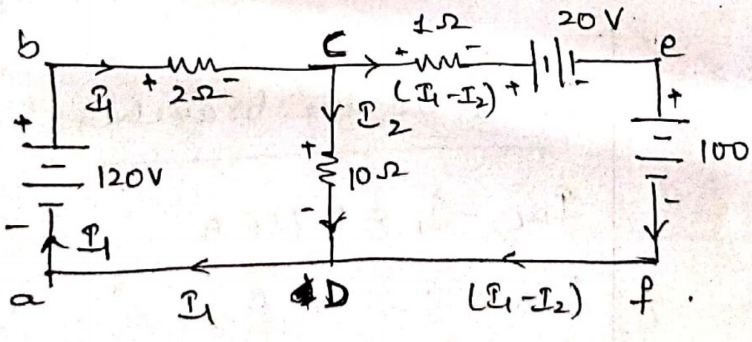
Q(9). In the ckt shown in fig what is the v/t across CD

i) if switch S is open

ii) switch S is closed



Sol^n: i) Switch S is open



Loop abcda

$$120 - 2I_1 - 10I_2 = 0$$

$$-2I_1 - 10I_2 = -120$$

$$I_1 + 5I_2 = 60 \quad \text{—} (1)$$

Loop cefdc

$$-(I_1 - I_2) - 20 - 100 + 10I_2 = 0$$

$$-I_1 + I_2 - 120 + 10I_2 = 0$$

$$-I_1 + 11I_2 = 120 \quad \text{—} (2)$$

solve eq^n 1 & 2

$$\cancel{I_1} + 5I_2 = 60$$

$$-\cancel{I_1} + 11I_2 = 120$$

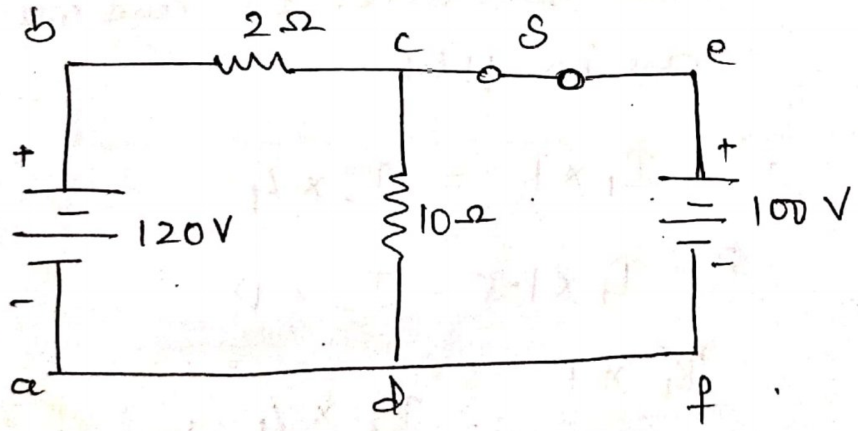
$$16 I_2 = 180$$

$$I_2 = 11.25\ A$$

$\therefore V_{cd} = I_2 \times R_{10} = 11.25 \times 10$

$$\boxed{V_{cd} = 112.5\ V}$$

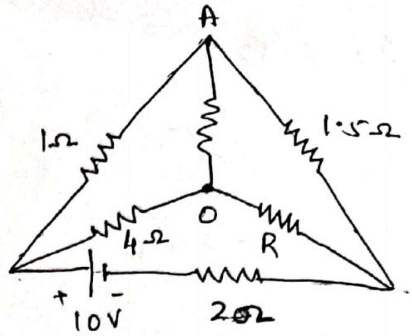
ii) <u>When switch 'S' is closed</u> :-



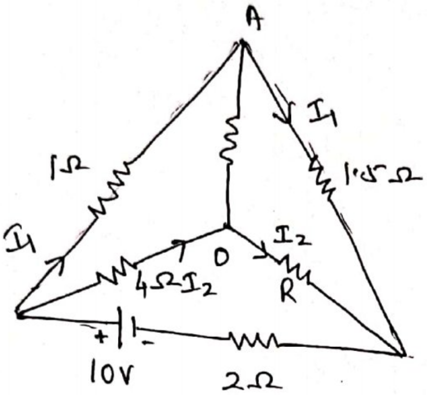
$$\boxed{V_{cd} = V_{ef} = 100\ V}$$

Q(10) Find the value of R and the c/t through it in the ckt shown if the c/t through AO is zero.

Model Q.P



Sol:-



The c/t through AO is zero

∴ the potential difference across AO is zero & A & O are at the same potential.

∴ the resistances 1Ω and 4Ω are in || el

$$\therefore I_1 \times 1 = I_2 \times 4$$

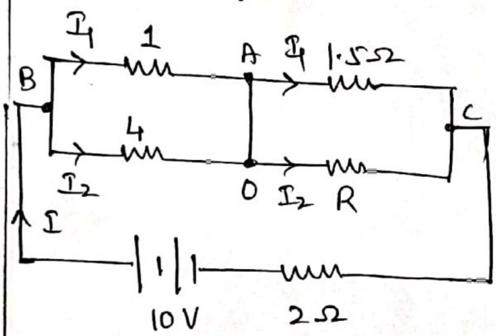
& $I_1 \times 1.5 = I_2 \times R$

$$\frac{\cancel{I_1} \times 1}{\cancel{I_1} \times 1.5} = \frac{\cancel{I_2} \times 4}{\cancel{I_2} \times R}$$

$$\therefore R = 1.5 \times 4 = 6\Omega$$

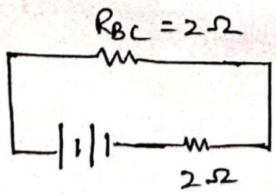
$$\boxed{R = 6\Omega}$$

⇓



$$R_{BC} = \frac{1 \times 4}{1+4} + \frac{1.5 \times 6}{1.5+6}$$

$$R_{BC} = 2\Omega$$



$$R_{eq} = 2 + 2 = 4\Omega$$

$$\therefore I = \frac{V}{R_{eq}} = \frac{10}{4} = 2.5A$$

$$I_R = I\left[\frac{1.5}{1.5+R}\right] = 2.5\left[\frac{1.5}{1.5+6}\right]$$

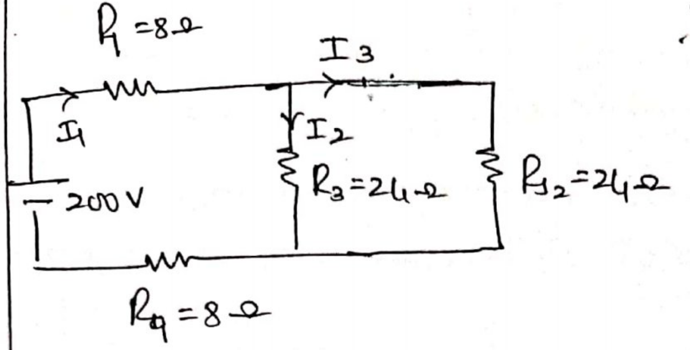
$$\boxed{I_R = 0.5A}$$

∴ the value of $\underline{R = 6\Omega}$

& the c/t through R $\underline{I_R = 0.5A}$

step 3 :- R_2, R_P, & R_8 are in series

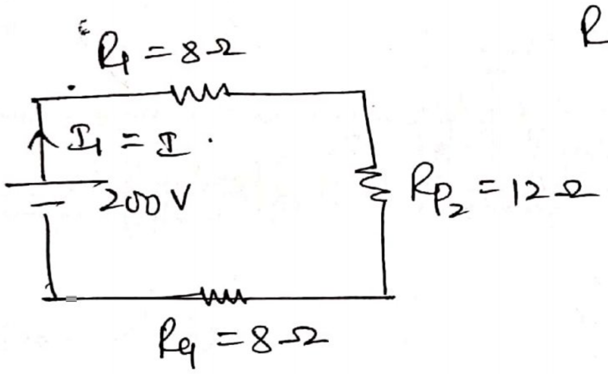
$\therefore R_{s_2} = 6 + 12 + 6 = 24\,\Omega$



step 4 :- R_{s_2} & R_3 are in ||el

$$R_{P_2} = \frac{R_{s_2} \times R_3}{R_{s_2} + R_3}$$

$$= \frac{24 \times 24}{24 + 24} = 12\,\Omega$$



step 5 :- R_1, R_{P_2} & R_9 are in series

$$\therefore R_{eq} = 12 + 8 + 8 = 28\,\Omega$$

$$\therefore I_1 = I = \frac{V}{R_{eq}} = \frac{200}{28} = 7.142\ A$$

from step (3) fig

$$I_3 = I_1 \left[\frac{R_3}{R_{s_2} + R_3} \right] = 7.142 \left[\frac{24}{24 + 24} \right] = 3.571\ A$$

from step (1) fig

$$I_5 = I_3 \left[\frac{R_4}{R_{s_1} + R_4} \right] = 3.571 \left[\frac{24}{24 + 24} \right] = 1.7855\ A$$

$$\therefore P_{16\Omega} = I_5^2 R_6 = (1.7855)^2 \times 16 = 51.008\ \text{watts}$$

$$\therefore \boxed{P_{16\Omega} = 51\ \text{watts}}$$