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1. DC circuit analysis
2. magnetic circuit analysis
3. Single phase AC circuits analysis
4. 3 phase AC circuit analysis
5. Power System components

$R = \rho \frac{l}{A}$

$P = V^2/R$

$P \propto 1/R$

$P \propto \frac{1}{l}$

less length
more power
less resistance

Assessment

- 10% Quiz
- 5th Calender week
- 30 minutes

Continuous Assessment
- 20%
- 2 marks each quiz
imm after every class
5th calender week
- 10-15 min

In sem
- 20%
- 90 min
- 4 ques - 10 marks each

End semester
- 50%
- 180 min
- 5 ques - 50 marks

References for Numericals

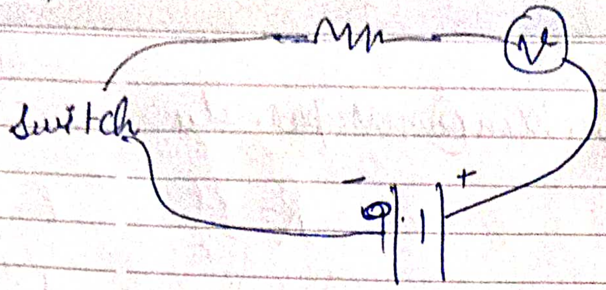
1. Hughes E. Electrical and Electronic Techology (12e) Pearson Education
2. BET
3.
4.

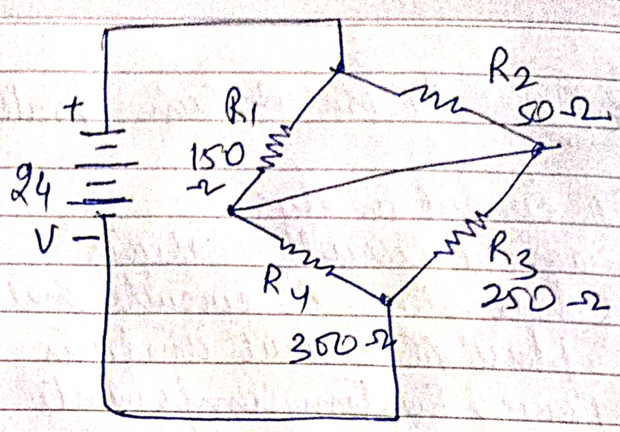
Scientific Calculator
- Casio fx-991ES plus (2nd edition) [non graphical non programmable]

What is an electric Circuit?

An inter connection of simple electrical devices with at least one closed path in which current may flow.
- Consists of a source of electrical energy, elements that either transform, dissipate or store energy, connecting wires
- To prevent power overload, circuits often include fuse or circuit breaker.

WORK TO DO





Circuit Elements

* Active and Passive : • Active elements: voltage & current sources.
  • Passive elements: Resistor, Inductor, capacitor.

APPOINTMENTS

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* Linear & Non linear elements: • Linear: Resistor, Inductor, capacitor
  • Non-linear: Diode, LDR (Light dependent Resistor) Thermistor, transistor

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* Unilateral & Bilateral: Unilateral (current flow in one direction)
  : Diode, Transistor

PHONES

Bilateral: Resistor, Inductor, capacitor

* Lumped & distributed: Lumped elements are simplified version of distributed elements.

[Our study is limited to lumped linear bilateral circuit elements.]

MAY 2011

Wk.	S	M	T	W	T	F	S
19	1	2	3	4	5	6	7
20	8	9	10	11	12	13	14
21	15	16	17	18	19	20	21
22	22	23	24	25	26	27	28
23	29	30	31				

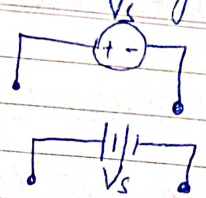
JUNE 2011

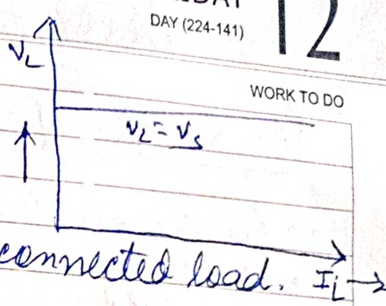
Wk.	S	M	T	W	T	F	S
23				1	2	3	4
24	5	6	7	8	9	10	11
25	12	13	14	15	16	17	18
26	19	20	21	22	23	24	25

Active elements - Sources

Voltage Source

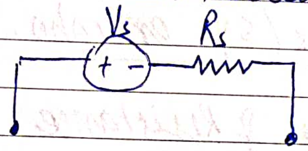
Ideal Voltage Source (DC)

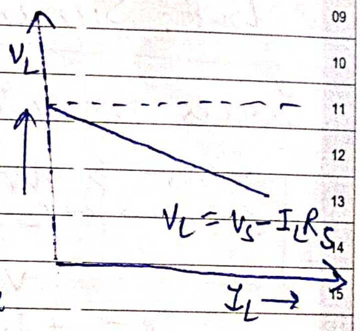




- Ideal: maintains constant voltage irrespective of connected load.
- Internal Resistance $R_S = 0$

- Practical: (Real voltage source)
  - Terminal voltage changes based on the connected load.
  - Internal Resistance $R_S \neq 0$
    ↓
    should be small.

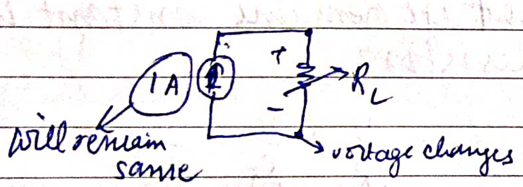


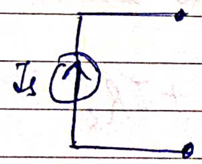


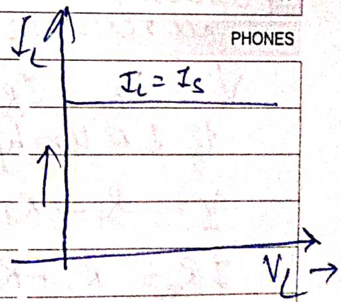
Current Source

- Ideal: maintains constant current irrespective of the load connected.
  - Internal Resistance $R_S = \infty$

Ideal Current Source (DC)

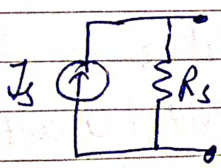


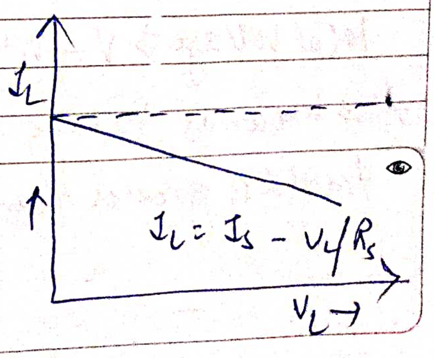




- Practical (Real current Source)
- Output current changes based on the connected load.
- Internal Resitance $R_s < \infty$
  ↘ v. high

if $R_S = \infty$
Practical current source = ideal.





PASSIVE ELEMENTS

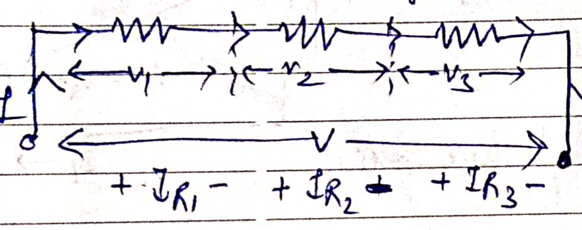
WORK TO DO

RESISTOR [energy consuming elements]

→ Passive electric device that dissipates energy in form of heat.
→ Resistance: Property which opposes the flow of current.
Symbol: R
Unit: Ohms (Ω)
Power consumed: I^2R

→ Conductance
· Reciprocal of resistance
APPOINTMENTS Symbol: G
Unit: Siemens (S) or mho ($\mho$)

Series Connection of Resistance



Current remain Constant in all resistors.

PHONES

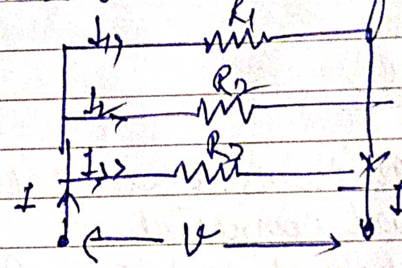
$V = IR_1 + IR_2 + IR_3$
if I is unity
$V = R_1 + R_2 + R_3$
$IR_{eq} = R_1 + R_2 + R_3$
$R_{net} = R_1 + R_2 + R_3$

total voltage ⇒ $V = V_1 + V_2 + V_3$

Also known as Voltage divider Circuit.

· total R is greater than the max Resistance

Parallel Connection of Resistance



Voltage Remains Constant in all Resistors.

14 Sunday

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

$\frac{V}{R_{eq}} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$

since V is constant.

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

$I = I_1 + I_2 + I_3$

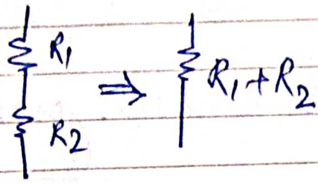
total Resistance is less than the least resistance

Also known as Current divider Circuit

JUNE 2011 JULY 2011

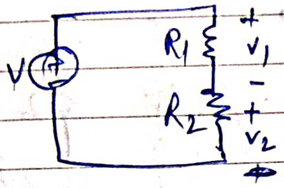
RESISTORS

Series Resistors



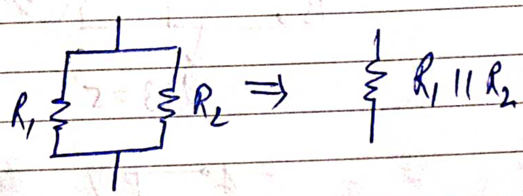
eq. Resistance = $\boxed{R_1+R_2}$

Voltage Divider



$$\boxed{v_1 = \frac{R_1}{R_1+R_2} V_s}$$ $$\boxed{V_2 = \frac{R_2}{R_1+R_2} V_s}$$

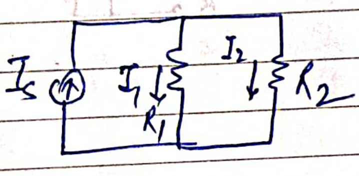
Parallel Resistors



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

$$\boxed{\frac{R_1 R_2}{R_1+R_2}}$$

Current Divider



$$\boxed{I_1 = \frac{R_2}{R_1+R_2} I_s}, \quad \boxed{I_2 = \frac{R_1}{R_1+R_2} I_s}$$

Delivering and absorbing power by a Source

- A battery is discharging (delivering power/energy) if,
  - Current coming out from positive (+) terminal
- A battery is charging (absorbing power/energy) if,
  current flowing into positive (+) terminal

* when current flows through a resistor,
  - Power is dissipated.

SEPTEMBER							2011
Wk.	S	M	T	W	T	F	S
36					1	2	3
37	4	5	6	7	8	9	10
38	11	12	13	14	15	16	17
39	18	19	20	21	22	23	24
40	25	26	27	28	29	30	

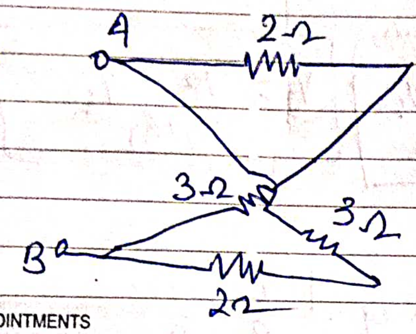
OCTOBER							2011
Wk.	S	M	T	W	T	F	S
40	30	31					1
41	2	3	4	5	6	7	8
42	9	10	11	12	13	14	15
43	16	17	18	19	20	21	22
44	23	24	25	26	27	28	29

WORK TO DO

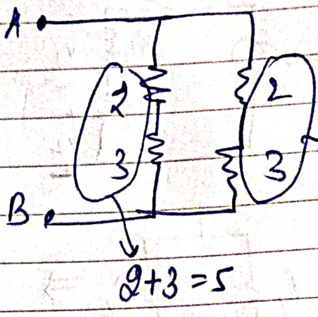
ILLUSTRATIONS - 1

Find the equivalent resistance of the networks given below.

Q1)



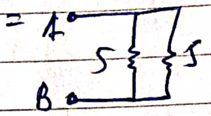
⇒



$2+3=5$

$2+3=5$

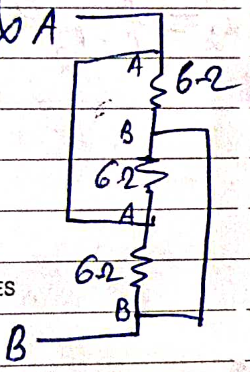
APPOINTMENTS



$$\Rightarrow \frac{1}{R_{eq}} = \frac{1}{5} + \frac{1}{5} = \frac{2}{5}$$

$$R_{eq} = 5/2\ \Omega$$

Q2)



PHONES

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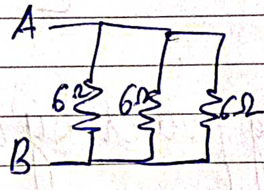
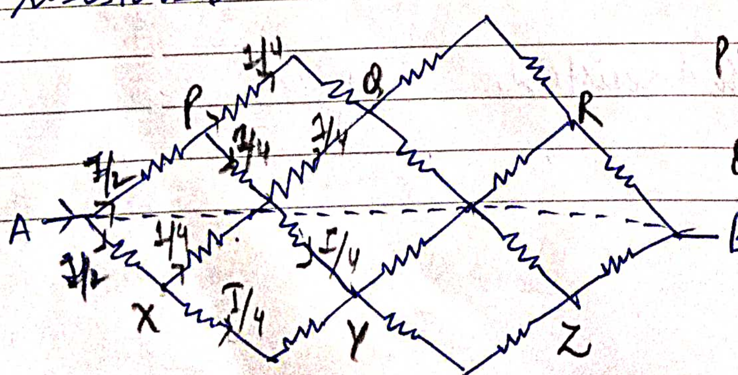


$$\therefore \frac{1}{R_{eq}} = \frac{1}{6} + \frac{1}{6} + \frac{1}{6} = \frac{3}{6}$$

$$R_{eq} = 6/3 = 2\ \Omega$$

Q3)
Imp

Determine the R_{eq} between A and B for given resistive network with 1 Ω resistors.



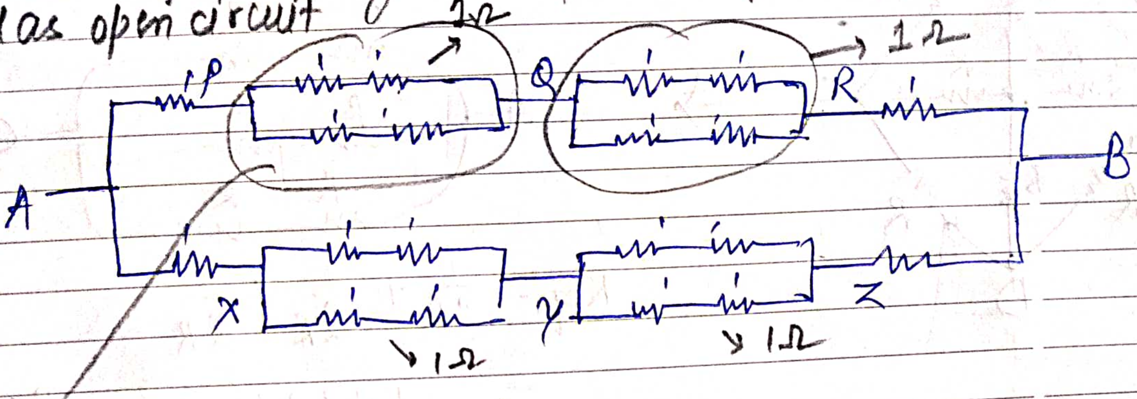
P & X = same potential
Q ≡ Y, R ≡ Z

HORIZONTAL WAY OF SYMMETRY.

Step 2: Fold along bisector

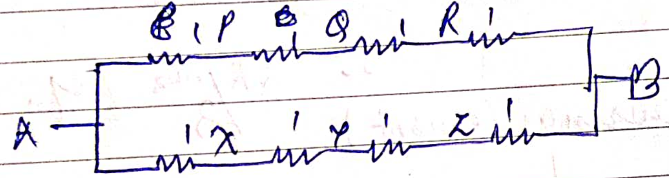
WORK TO DO

current cannot flow through same potential points hence is can be treated as open circuit



$\frac{1}{Req} = \frac{1}{2} + \frac{1}{2}$

$\frac{2}{2} = 1$



$\frac{1}{Req} = \frac{1}{4} + \frac{1}{4} = \frac{2}{4} = Req = 4/2 = 2\Omega$

APPOINTMENTS

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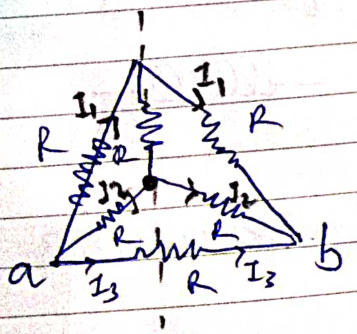
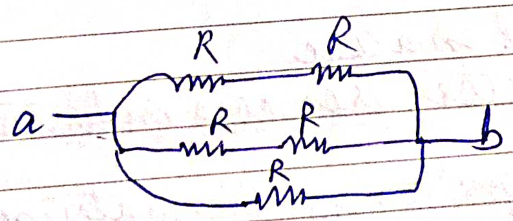
Q44 Determine the equivalent resistance between points A and C for given resistive network.

VERTICAL PLANE OF SYMMETRY

PHONES



$\Rightarrow$



Points of vertical plane of symmetry have same potential
$\rightarrow$ Branches have same current
Points having same potential means no current can pass through them so,

$\frac{1}{2R} + \frac{1}{2R} + \frac{1}{R}$

$\Rightarrow \frac{1+1+2}{2R}$

$= 4/2R$

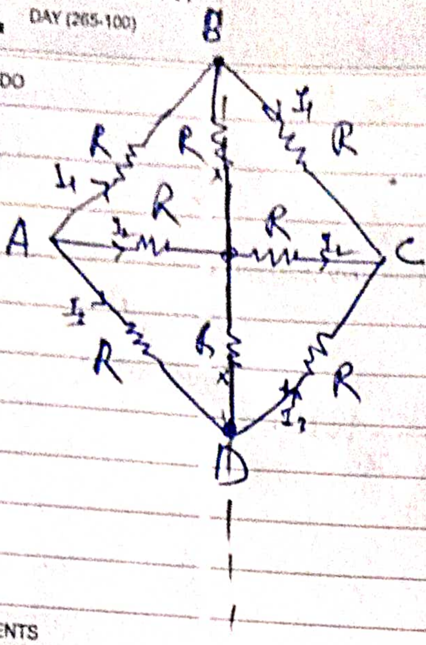
$2R/4 = \boxed{R/2 = Req}$

SEPTEMBER							2011
Wk.	S	M	T	W	T	F	S
35					1	2	3
36	4	5	6	7	8	9	10
37	11	12	13	14	15	16	17
38	18	19	20	21	22	23	24
39	25	26	27	28	29	30	

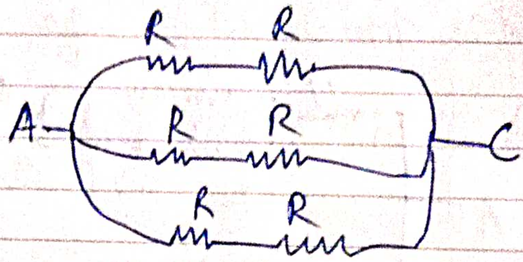
OCTOBER							2011
Wk.	S	M	T	W	T	F	S
40							1
41	2	3	4	5	6	7	8
42	9	10	11	12	13	14	15
43	16	17	18	19	20	21	22
44	23	24	25	26	27	28	29
45	30	31					

WORK TO DO

856



$\Rightarrow$



$$\frac{1}{R_{eq}} = \frac{1}{2R} + \frac{1}{2R} + \frac{1}{2R}$$

$$\frac{1+1+1}{2R} = \frac{3}{2R}$$

$\therefore \frac{2R}{3}\Omega \; R_{eq}.$

APPOINTMENTS

09

10 **Inductor** (Energy storing Element)

11

12 Inductance is property of coil that opposes any change in amount of
13 current flowing. It is caused due to self inductance as an
14 EMF is induced in inductor due to changed in current.
15

16 • Passive electric device that stores energy in its magnetic field when
17 current flows through it.
18

PHONES A coil of wire wound on a core
Exg: Air core inductor, iron core inductor

We usually use [Ferromagnetic magnetic material] to make inductor
↓ good permeability

Inductance: property that oppose rate of change of current
Symbol: L
Unit: Henry (H)

• The voltage across inductor is $\propto$ to the rate of change of current

$$V_L = L\frac{di}{dt}.$$

JULY 2011

Wk.	S	M	T	W	T	F	S
27	31					1	2
28	3	4	5	6	7	8	9
29	10	11	12	13	14	15	16
30	17	18	19	20	21	22	23
31	24	25	26	27	28	29	30

AUGUST 2011

Wk.	S	M	T	W	T	F	S
32		1	2	3	4	5	6
33	7	8	9	10	11	12	13
34	14	15	16	17	18	19	20
35	21	22	23	24	25	26	27
36	28	29	30	31			

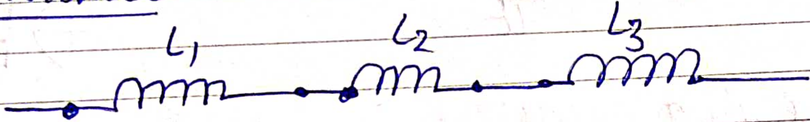
Inductive Circuit

For a coil uniformly wound a non-magnetic core of uniform cross section, self inductance is given by

$$L = \frac{\mu_0 A N^2}{l}$$

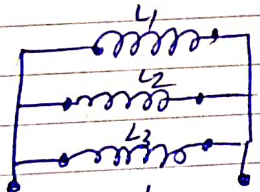
Where, l = length of the magnetic circuit in meters
A = cross sectional area in sq. meters
μ_0 = Permeability of air = $4\pi \times 10^{-7}$
N = No of turns in the coil.

Equivalent Inductance



In series = $L_{eq} = L_1 + L_2 + L_3 + \dots L_n$

In parallel



$$\frac{1}{L_{eq}} = \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3} + \dots \frac{1}{L_n}$$

Energy stored in an Inductor

Instantaneous Power, $p = v_L i = L i \frac{di}{dt}$

- Energy absorbed in 'dt' time is $dw = Li\,di$
- Energy absorbed by the magnetic field when current increases from 0 to I amperes is,

$$W = \int_0^I Li\,di = \boxed{\frac{1}{2}LI^2}$$

APPOINTMENTS
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PHONES

OCTOBER 2011

Wk	S	M	T	W	T	F	S
40	30	31					1
41	2	3	4	5	6	7	8
42	9	10	11	12	13	14	15
43	16	17	18	19	20	21	22
44	23	24	25	26	27	28	29

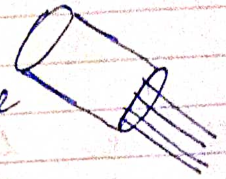
NOVEMBER 2011

Wk	S	M	T	W	T	F	S
45			1	2	3	4	5
46	6	7	8	9	10	11	12
47	13	14	15	16	17	18	19
48	20	21	22	23	24	25	26
49	27	28	29	30			

WORK TO DO

Capacitors

- Passive electric device that stores energy in the electric field between a pair of closely spaced conductors.



- Capacitance: property which opposes the rate of change of voltage

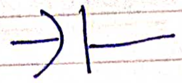
  Symbol: C

  Unit: ~~farad~~ Farad (F)

- The capacitive current is proportional to the rate of change of voltage across it.

APPOINTMENTS

$$i_c = C\frac{dv_c}{dt}$$



- Charge stored in a capacitor whose plates are maintained at constant voltage:

$$Q = CV \qquad \frac{Q}{V} = \text{constant} \rightarrow [\text{capacitance}]$$

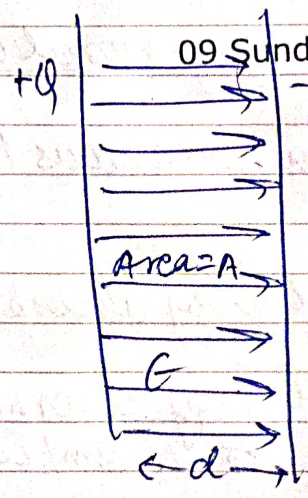
$$\text{Farad} = \frac{\text{coulomb}}{\text{volts}}$$

TERMINOLOGY

PHONES

Electric field strength, $E = \frac{V}{d}$ $\boxed{\text{volts/m}}$

Electric Flux density $= D = \frac{Q}{A}$ $\boxed{C/m^2}$



Permitivity of free space $= 8.854 \times 10^{-12}$ F/m

$\epsilon_0 = \frac{1}{\ldots} =$ [redacted]

Relative permittivity $= \epsilon_r$

- capacitance of parallel plate capacitor

$$\boxed{C = \frac{\epsilon_0 \epsilon_r A}{d}}$$

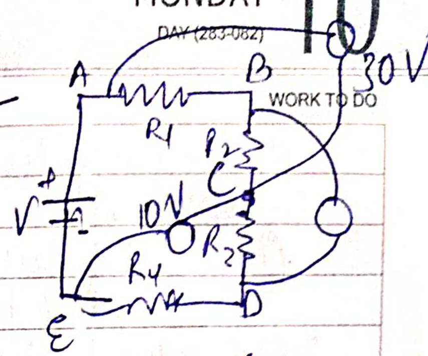
AUGUST 2011							
Wk.	S	M	T	W	T	F	S
32		1	2	3	4	5	6
33	7	8	9	10	11	12	13
34	14	15	16	17	18	19	20
35	21	22	23	24	25	26	27
36	28	29	30	31			

SEPTEMBER 2011							
Wk.	S	M	T	W	T	F	S
36					1	2	3
37	4	5	6	7	8	9	10
38	11	12	13	14	15	16	17
39	18	19	20	21	22	23	24
40	25	26	27	28	29	30	

$P = VI$ $\quad P = \frac{V^2}{R}$

$P = I^2 R$ $\quad \boxed{V = IR}$

Q

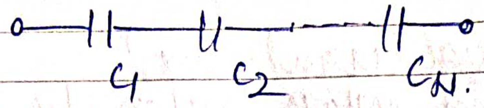


Source Voltage $= [V_{AB} + V_{BC}] + V_{CD} + V_{DE}$

$= 30 + 10V$

$= 40V.$

Equivalent Capacitance

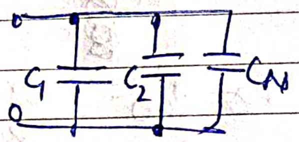


Capacitance in series

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} - - - - \frac{1}{C_N}$$

Capacitance in Parallel

$$C_{eq} = C_1 + C_2 + C_3 \cdots C_N$$



Energy Stored in a Capacitor

Instantaneous power. $p = v_C \times i = C v_C \frac{dv_C}{dt}$.

Energy supplied during 'dt' time is: $dw = C v_C dv_C$

Energy stored in the electric field when potential rises from 0 to V volts is

$$W = \int_0^V C v_C dv_C = \boxed{\frac{1}{2} CV^2 \text{ Joules}}$$

$\propto$

Illustrations & Star Delta

Two incandescent bulbs have following ratings:

Bulb 1 = 120V, 60W

Bulb 2 = 240V, 480W.

(a) Both of them are connected in series across a voltage source.

(i) Which will glow brighter and why?

(ii) What is the maximum voltage that can be applied so that none of the bulbs fuse.

WORK TO DO

(b) Now both of them are connected in parallel across a voltage source.

(i) which bulb will glow brighter and why?

(2) what is the maximum voltage that can be applied so that none of the bulbs fuse?

Ans

(A) (i) Same current will flow.

$P_1 = \frac{v^2}{R}$ $P_{60} = \frac{120 \times 120}{R}$ $R = \frac{120 \times \cancel{120}^{2}}{\cancel{60}}$

APPOINTMENTS

09 $I_{R_1} = \frac{60}{120} = 0.5A$ $60 = \frac{120 \times 120}{R}$ $= \underline{240\,\Omega}$

10

11 $P_2 = \frac{v^2}{R}$ $P_{480W} = \frac{240 \times 240}{R}$ $\Rightarrow R = \frac{\cancel{240}^{120} \times \cancel{240}}{\cancel{480}_{2}} = \underline{120\,\Omega}$

12

13 $I_{R_2} = \frac{480}{240} = 2A$

14 $\cancel{P \propto \frac{1}{R}}$

15

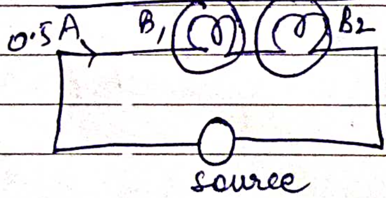
16 ~~Since Resistance is inversely proportional to Power, Hence~~

17 ~~Bulb 2w has less resistance and more Power.~~

18 ~~Hence it will glow brighter.~~

PHONES

(ii) series connection



max current permitted will be 0.5A, or else the Bulb 2 will fuse in case of 2A.

$P_1 = (0.5)^2 \times R_1 \Rightarrow (0.5)^2 \times 240\,\Omega = 60W$

$P_2 = (0.5)^2 \times 120\,\Omega = 30W$

$P_1 > P_2$, B_1 will glow brighter.

(ii) $V_{total} = 0.5 \times R_1 + 0.5 \times R_2$

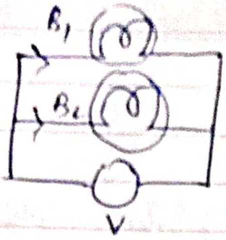
$= 0.5(R_1 + R_2)$

$0.5(360)$

$= \underline{180\,V} \rightarrow$ max voltage.

$\boxed{P = VI,\ P = \frac{V^2}{R}\ \ P = I^2R}$

B (i)



max voltage permitted = 120 V
↓
(Remains same)

In Case of 240, bulb will fuse.

$P_1 = \frac{V^2}{R} \Rightarrow \frac{120^2}{240} = 60\,W$

$P_2 = \frac{V^2}{R} = \frac{120^2}{120} = 120\,W.$

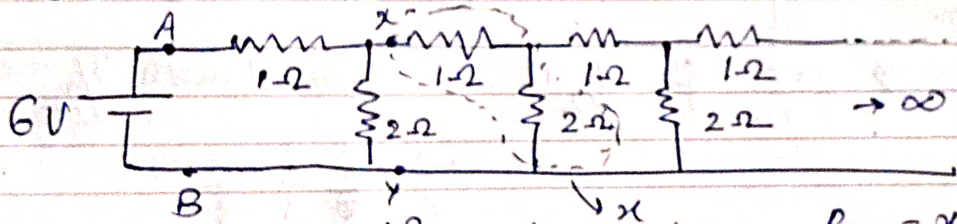
$\because$ Since $P_2 > P_1$
Bulb 2 will glow brighter.

(ii) 120 V is max voltage that can be applied, as Same voltage flows.

Illustration - 2

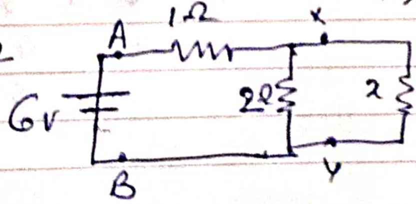
- what is the equivalent resistance across the terminals A & B in the network shown.

[Infinite ladder Circuit]



$R_{xy} = x\,\Omega$

Let $R_{AB} = x\,\Omega$



$\frac{1}{R_{xy}} = \frac{1}{x} + \frac{1}{2}$

$\frac{1}{R_{xy}} = \frac{2+x}{2x}$

$R_{xy} = \frac{2x}{2+x}$

$R_{AB} = 1 + \frac{2x}{2+x}$

$x = 1 + \frac{2x}{2+x}$

$x = \frac{2+x+2x}{2+x} \Rightarrow \cancel{2x} + x^2 = 2 + x + \cancel{2x}$

$\cancel{20x + x^2 = 20 + x + 20x}$

$\cancel{x^2 - x - 20 = 0}$

$x^2 - x - 2 = 0$

$x^2 - 2x + x - 2 = 0$

$x(x-2) + 1(x-2) = 0$

$(x+1)(x-2) = 0$

$\times\ x = -1 \quad x = 2\,\Omega \quad \therefore$

$R_{AB} = x\,\Omega = 2\,\Omega$

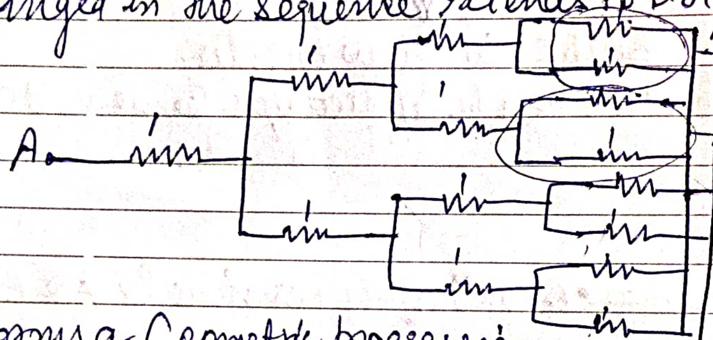
WORK TO DO

Illustration-3

15 resistors are connected as shown in diagram. Each of the resistors has resistance $1\,\Omega$.

(a) Find the equivalent resistance of the network between A & B.

(b) What will be the equivalent resistance of this network if the resistors arranged in the sequence extends to infinity?



$\left[\left((1 \| 1)+1\right) \| \left((1 \| 1)+1\right)\right]+1$

$\|$

$\left[(1 \| 1+1) \| (1 \| 1)+1\right]+$

APPOINTMENTS

09

10

11 This forms a Geometric progression.

12

13 Solving Part 1 $\Rightarrow \frac{1}{1}+\frac{1}{1} = \frac{2}{1} = \frac{1}{2}+1 = \frac{3}{2}$ is $\|$ with $3/2$

14

15 (a)

$\therefore \frac{1}{R} = \frac{2}{3}+\frac{2}{3}$

16

17 $3/4$ is in series with 1

18 $= \frac{4}{3} \Rightarrow 3/4$

PHONES

$3/4+1 = 7/4$

Similarly $7/4$ is in $\|$ with $7/4$.

$\therefore \frac{1}{R} = \frac{4}{7}+\frac{4}{7}$

$= 8/7 \Rightarrow \boxed{7/8\,\Omega}$

$7/8\,\Omega$ is in series with $1\,\Omega$

$= \frac{7}{8}+1 = \boxed{15/8\,\Omega} = 1.875\,\Omega$

Ans//

AUGUST 2011

Wk.	S	M	T	W	T	F	S
32		1	2	3	4	5	6
33	7	8	9	10	11	12	13
34	14	15	16	17	18	19	20
35	21	22	23	24	25	26	27
36	28	29	30	31			

SEPTEMBER 2011

Wk.	S	M	T	W	T	F	S
36					1	2	3
37	4	5	6	7	8	9	10
38	11	12	13	14	15	16	17
39	18	19	20	21	22	23	24
40	25	26	27	28	29	30	

(b) this extends to a Geometric Progression.

$a, ar, ar^2, ar^3, ar^4 \ldots ar^{n-1}$

1st term = a

n^{th} term = $a(r^{n-1})$

Sum of n terms = $\dfrac{a(1-r^n)}{1-r}$

$\frac{ar}{a} = R = \frac{ar^a}{a}$

$R = \underline{\underline{r}}$

Sum of terms upto ∞

$$S_\infty = \frac{a}{1-r}$$

2, 4, 8, 16, 32

$\frac{4}{2} = 2$ in each 2, 2 resistances are in || therefore

$r = 1/2$

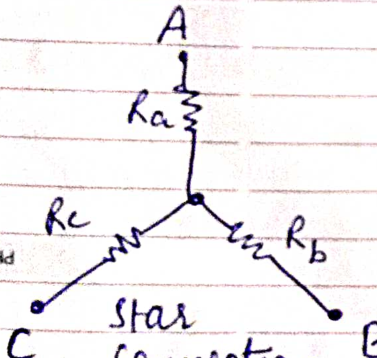
Here $a = 1$

$r = 1/2$ because 1 and 1 in parallel

$$\boxed{S_\infty = \frac{1}{1-1/2} = \frac{1}{1/2} = \underline{\underline{2\Omega}}}$$

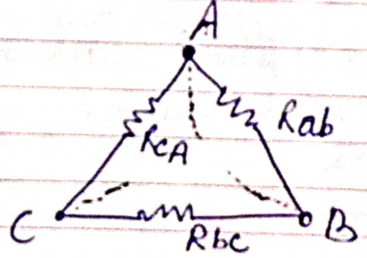
Star Delta Transformation.

[Network reduction Technique]



Star connection

$\longleftrightarrow$



Delta Connection

(1) From Delta to Star

$$R_A = \frac{R_{CA} * R_{AB}}{R_{CA} + R_{AD} + R_{BC}}$$

$$R_B = \frac{R_{AB} * R_{BC}}{R_{CA} + R_{AD} + R_{BC}}$$

$$R_C = \frac{R_{CA} * R_{BC}}{R_{CA} + R_{AD} + R_{BC}}$$

WORK TO DO

(2) Star to Delta

$$R_{ab} = R_a + R_b + \frac{R_a R_b}{R_c}$$

$$R_{bc} = R_b + R_c + \frac{R_b R_c}{R_a}$$

$$R_{ca} = R_c + R_a + \frac{R_c R_a}{R_b}$$

* Balanced Δ and ⋏

$R_\star = R_A = R_B = R_C$

$R_\Delta = R_{AB} = R_{BC} = R_{CA}$

$$\boxed{R_\Delta = 3R_\star}$$

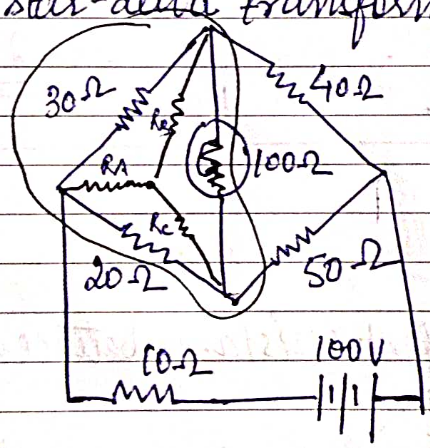
$$\boxed{R_\star = \frac{1}{3} R_\Delta}$$

Illustrations-4

APPOINTMENTS

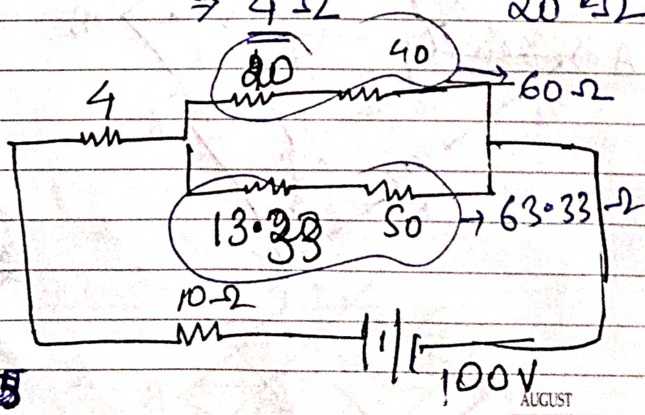
09 For the circuit shown, determine the total power supplied by the
10 source using star-delta transformation.

11
12
13
14
15
16
17
18



PHONES

Sol converting to star. $R_A = \frac{20\times 30}{150} \Rightarrow 4\,\Omega$, $R_B = \frac{30\times 100}{150} = 20\,\Omega$, $R_C = \frac{20\times 100}{150} = 40/3\,\Omega = 13.33\,\Omega$



$$\frac{1}{60} + \frac{1}{63.33}$$

$$\frac{60 \times 63.33}{60 + 63.33} = 30.81$$

$R_{total} = 4 + 10 + 30.81 = \boxed{44.81\,\Omega}$

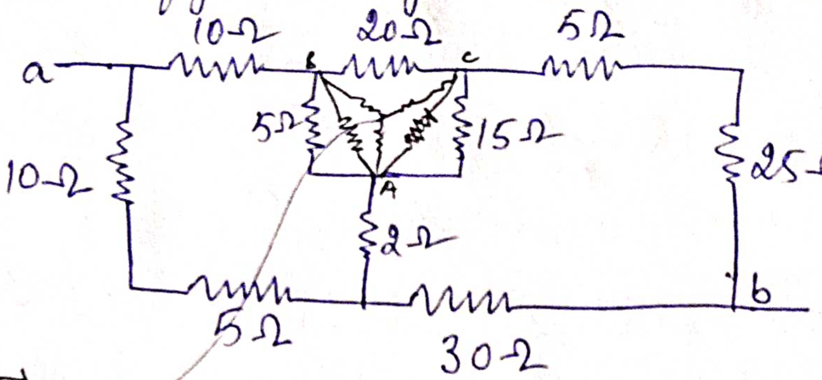
44.8107Ω

P = 223.16 W

$\rightarrow P = \frac{V^2}{R} \rightarrow \frac{100 \times 100}{44.81} = \boxed{223.16\,W}$

Illustration-5

Determine the resistance between the terminals a and b of the network shown in figure, using star Delta transformation.

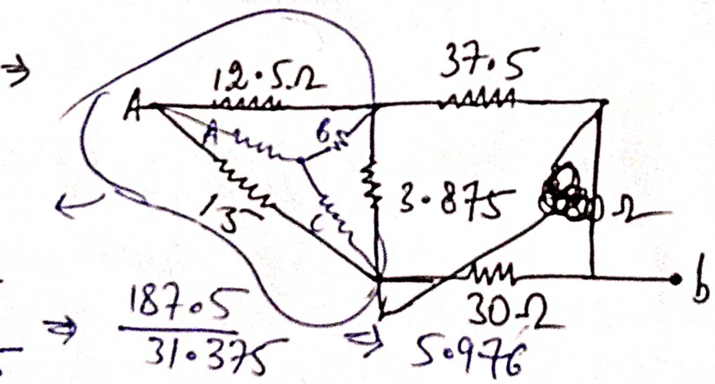


→ convert to star transformation

$R_A = \frac{5 \times 15}{870}$ $\quad R_B = \frac{5 \times 20}{240}$ $\quad R_C = \frac{20 \times 15}{240}$

$R_A = 15/8 = 1.875$ $\quad R_B = 5/2 = 2.5$ $\quad R_C = 15/2 = 7.5$

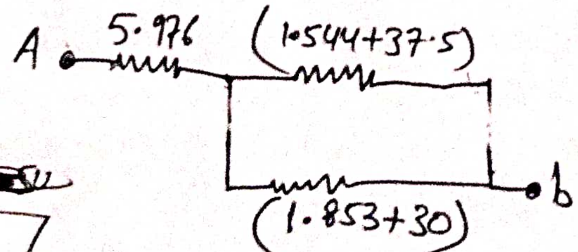
→



$A = \frac{12.5 \times 15}{31.375} \Rightarrow \frac{187.5}{31.375} \Rightarrow 5.976$

$B = \frac{12.5 \times 3.875}{31.375} \Rightarrow \frac{48.4375}{31.375} \Rightarrow 1.544$

$C = \frac{15 \times 3.875}{31.375} \Rightarrow \frac{58.125}{31.375} \Rightarrow 1.853$



$\frac{3799.8}{123.33}$

$R_{ab} =$

$\boxed{23.518\,\Omega}$

Q Two incandescent bulbs of 40 W and 60 W are connected in series accross mains. Assuming the voltage to be same.

Ans $P = \frac{V^2}{R}$ $\boxed{P \propto \frac{1}{R}}$

$R_{40} = \frac{x^2}{40}$, $R_{60} = \frac{x^2}{60}$

when connected in series current flowing through each element is same.

Then $P_{40W} = I^2R > P_{60} = I^2R_{60}$

40 W will glow brighter

$P_{40} = \left(\frac{40}{x}\right)^2 \times R_{40W}$

$= \left(\frac{40}{\cancel{x}}\right)^{\cancel{2}} \times \frac{\cancel{x^2}}{\cancel{40}} = 40W$

$P_{60} = \left(\frac{40}{x}\right)^2 \times \frac{x^2}{60} = \frac{160}{6}$

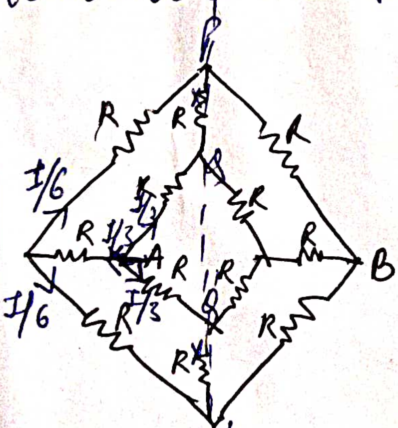
$\frac{40}{\cancel{x}} \times \frac{40}{\cancel{x}} \times \frac{\cancel{x} \times \cancel{x}}{60} = \frac{160}{6}$

$= 26.66$ W

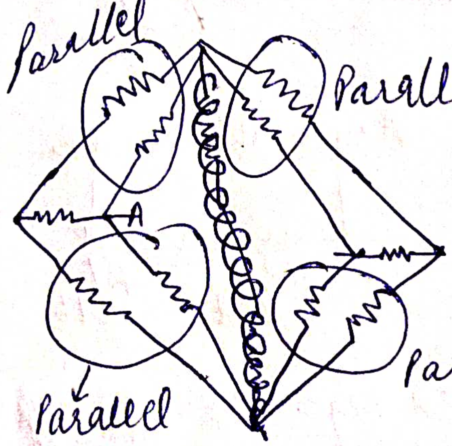
$P_{tot} = 40 + 26.66$

$= \underline{66.667 \text{ W}}$

* Homework-1 and Homework-2



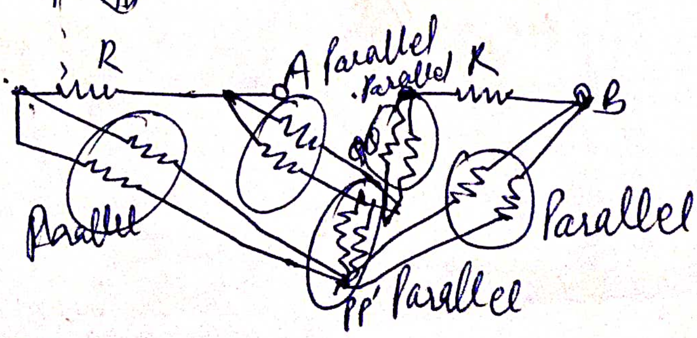
⇒

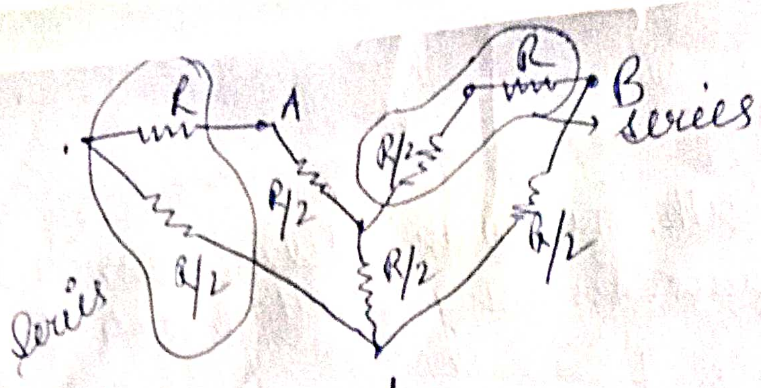


Fold into halfs horizontally

⇓

⇒





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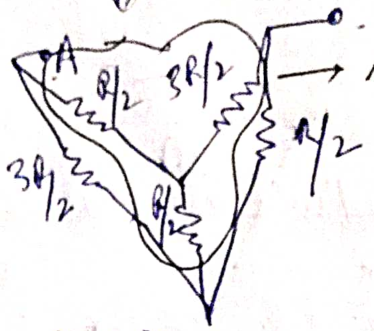
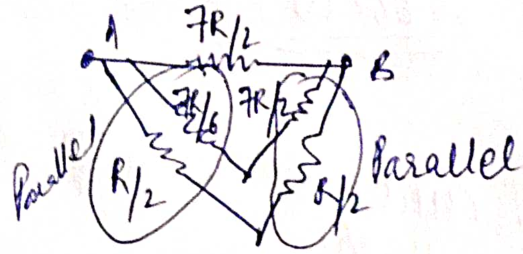


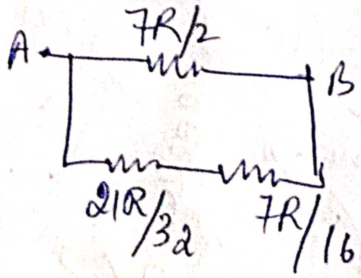
→ convert to Delta

$$R_{AB} = R/2 + R/2 + \frac{R/2 \times R/2}{3R/2} = R + \frac{R^{\cancel{2}}}{4} \times \frac{2}{3\cancel{R}} = R + \frac{R}{6} = 7R/6$$

$$R_{BC} = \frac{3R}{2} + \frac{R}{2} + \frac{3R/2 \times R/2}{R/2} = 2R + \frac{3R^{\cancel{2}}}{4} \times \frac{2}{\cancel{R}} = 2R + \frac{3R}{2} = 7R/2$$

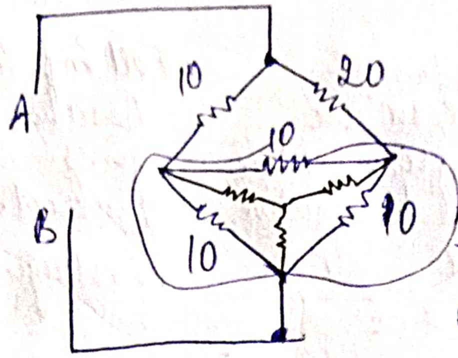
$$R_{AC} = 3R/2 + R/2 + \frac{3R/2 \times R/2}{R/2} = 2R + \frac{3R^{\cancel{2}}}{\cancel{4}2} \times \frac{\cancel{2}}{\cancel{R}} \Rightarrow 2R + \frac{3R}{2} \Rightarrow 7R/2$$





$\Rightarrow R_{eq} = \frac{5R}{6}$ Ans //

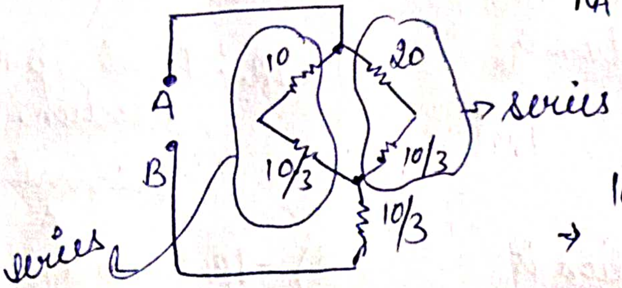
Homework - 1



$\rightarrow \Delta$ to ⅄

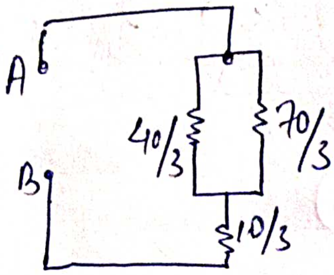
$R_A = \frac{100}{30}$, $R_B = \frac{100}{30}$ $R_C = \frac{100}{30}$.

$R_A = 10/3 = R_B = R_C$



$\rightarrow \quad 10 + \frac{10}{3}, \qquad 20 + \frac{10}{3}$

$40/3 \qquad 70/3$



$\frac{1}{R} = \frac{3}{40} + \frac{3}{70}$.

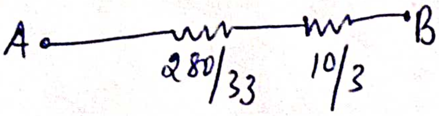
$\frac{1}{R} = \frac{21+12}{280}$

$\frac{1}{R} = \frac{33}{280}$

$R = 280/33$

10	40, 70
4	4, 7
7	1, 7
	1, 1

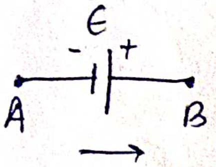
3	33, 3
11	11, 1
	1, 1



$\Rightarrow R_{eq} = \frac{280}{33} + \frac{10}{3}$

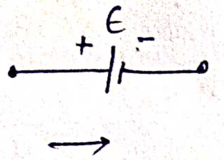
$= \frac{280 + 110}{33} = \frac{390}{33}$ Ans $\Rightarrow \boxed{130/11}$

Sign Convention for Kirchoff's Voltage Law (KVL)



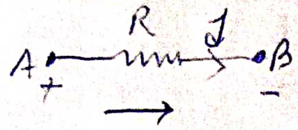
Rise in potential because we are going from negative terminal of the battery to positive terminal

EMF = $+E$



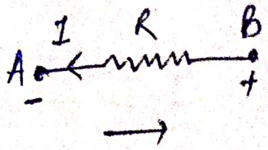
Fall in potential because, we are going from positive terminal to negative terminal

$\therefore$ EMF = $-E$



Fall in potential because we are going in the direction of current.

$\therefore$ Voltage drop $= -IR$

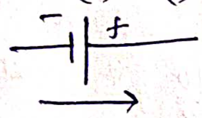


Rise in potential bcz we are going in opp direction of current.

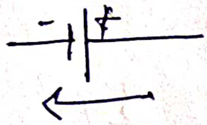
$\therefore$ Voltage gain $= +IR$

(a) Sign Convention for Emfs.

① $+E \rightarrow$ Travel direction is $(-)$ to $(+)$

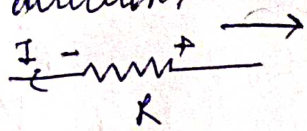


② $-E \rightarrow$ Travel direction is $(+)$ to $(-)$

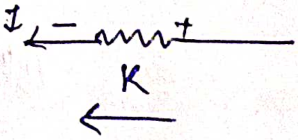


(b) Sign Convention for resistors

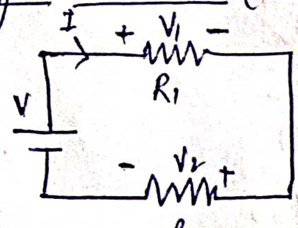
① $+IR$: Travel opp to current direction.



② $-IR$: Travel in current direction



Voltage Division (in series circuit)



$V = V_1 + V_2$

$V = V_1 + V_1\left(\frac{R_2}{R_1}\right)$

$V_1 = V\left(\frac{R_1}{R_1+R_2}\right)$

$V_2 = V\left(\frac{R_2}{R_1+R_2}\right)$

$V_1 = IR_1$

$V = IR_1 + IR_2$

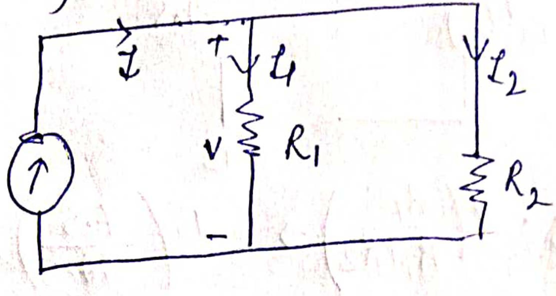
$(R = R_1 + R_2)$

$$\boxed{\frac{V_1}{V} = \frac{\cancel{I}R_1}{\cancel{I}(R_1+R_2)}}$$

$V_2 = IR_2$

$$\boxed{\frac{V_2}{V} = \frac{\cancel{I}R_2}{\cancel{I}(R_1+R_2)}}$$

Current Division (in Parallel circuit)



$I = I_1 + I_2$ $\quad R_T = \frac{R_1 R_2}{R_1 + R_2}$

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

$I_1 = \frac{V}{R_1}$ | $\frac{I_1}{I}$ and $\frac{I_2}{I}$

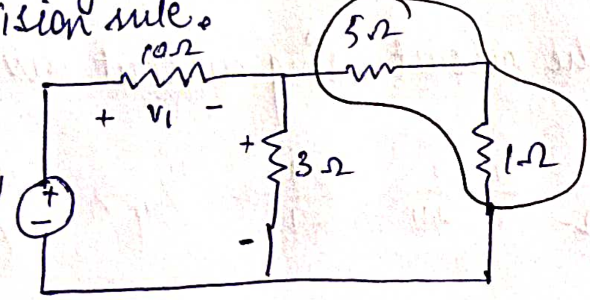
$I_2 = \frac{V}{R_2}$ | $I_1 = I\left(\frac{R_2}{R_1+R_2}\right)$ $\quad I_2 = I\left(\frac{R_1}{R_1+R_2}\right)$

$I = I_1 + I_2$ | $I_1 = I\left(\frac{R_2}{R_1+R_2}\right)$

$I = I_1 + I_1\left(\frac{R_1}{R_2}\right)$ | $I_2 = I\left(\frac{R_1}{R_1+R_2}\right)$

Illustration-1

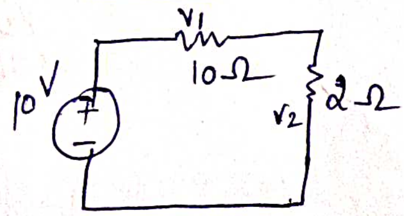
Find voltage V_1 and V_2 as marked in the given Circuit using Voltage and division rule.



→ series $(5+1)\Omega \parallel 3\Omega$

$6 \parallel 3\Omega$

$\frac{1}{R} = \frac{1}{6} + \frac{1}{3} = \frac{3}{6} = \boxed{6/3 = 2\Omega}$

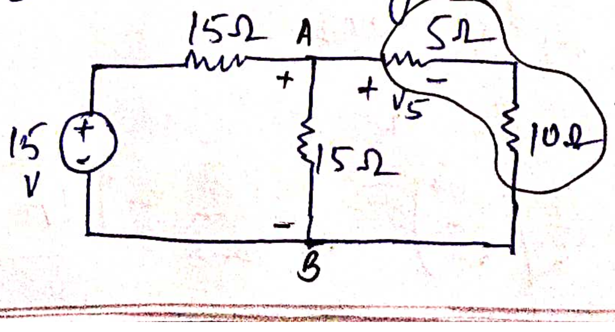


$V_1 = V\left(\frac{R_1}{R_1+R_2}\right) \Rightarrow \quad V_1 = 10\left(\frac{10}{12}\right) = \frac{100}{12} = \frac{50}{6} = \boxed{\text{Volts } 25/3 = 8.33}$

$V_2 = V\left(\frac{R_2}{R_1+R_2}\right) \Rightarrow \quad V_2 = 10\left(\frac{2}{12}\right) = \frac{20}{12} = 10/6 = \boxed{5/3 \text{ volts} = 1.66}$

Illustration-2

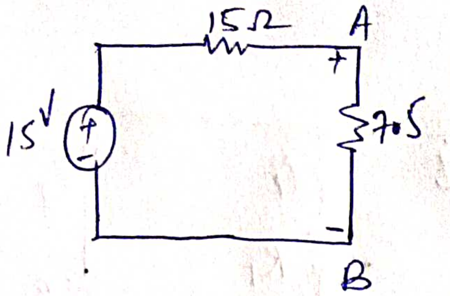
Find voltage V_5 as marked in the given Circuit using voltage division rule.



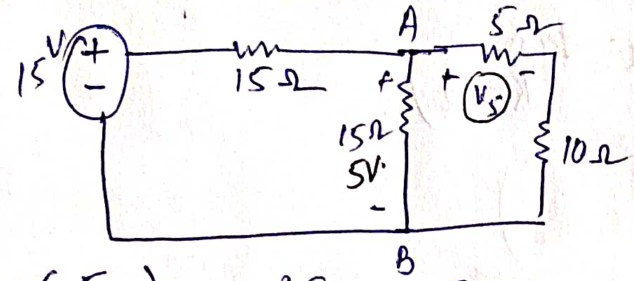
→ $(5+10) \parallel 15$

$= 15 \parallel 15$

$\frac{1}{R} = \frac{1}{15} + \frac{1}{15} = \frac{2}{15}$ $\quad \boxed{R = 15/2\,\Omega}$



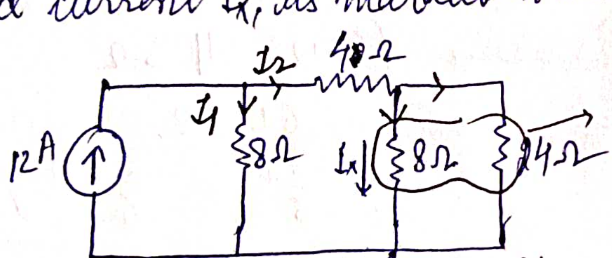
$$V_{AB} = V\left(\frac{R_1}{R_1+R_2}\right) \Rightarrow 15\left(\frac{7.5}{22.5}\right) = \frac{112.5}{22.5} = \underline{\underline{5 \text{ volts}}}$$



$$V_5 = \underbrace{5\left(\frac{5}{15}\right)}_{V\left(\frac{R_1}{R_1+R_2}\right)} = \frac{25}{15} = 5/3 = \underline{\underline{1.667 \text{ volts}}}$$

Illustration-3

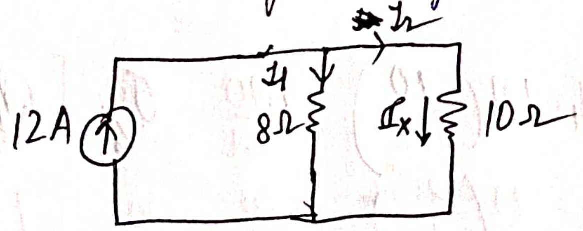
Find current I_x, as marked in the circuit using current division rule.



$$\frac{1}{8}+\frac{1}{24} = \frac{3+1}{24} = 4/24 \Rightarrow 24/4 = \underline{\underline{6Ω}}$$

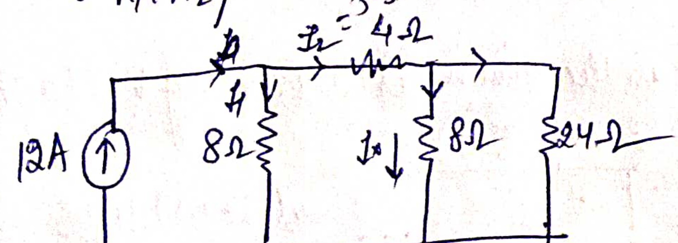
in series with 4Ω

higher current will go to ~~higher~~resistance
lower current will go with ~~low~~ higher resistance



$$I_2 = I\left(\frac{R_1}{R_1+R_2}\right) \Rightarrow I_2 = 12\left(\frac{8}{18}\right) = \frac{\cancel{12}^{2}\times 8}{\cancel{18}_{3}} = \boxed{16/3 \text{ A}}$$

Redrawing



$$I_x = I\left(\frac{R_2}{R_1+R_2}\right)$$

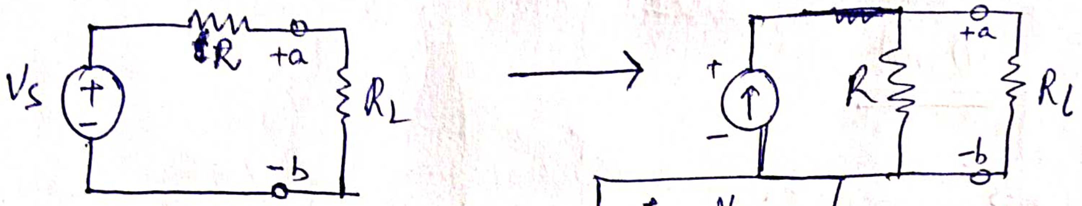
$$I_x = 16/3\left(\frac{24}{32}\right) \Rightarrow \frac{16}{\cancel{3}}\left(\frac{\cancel{24}^{8}}{32}\right) = \frac{\cancel{16}\times 8}{\cancel{32}_{2}} = \boxed{4A}$$

Source Transformation (V.V.V.V.V imp)

Practical Voltage Source $\longleftrightarrow$ Practical Current Source

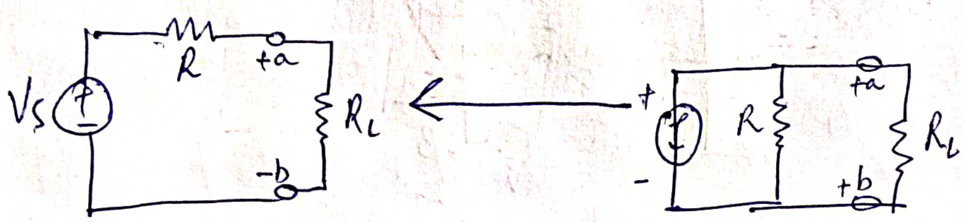
(Ideal voltage source in series with I_r)

(Ideal current source in $\parallel$ with I_r)



R = Internal Resistance

$$\boxed{I_s = \frac{V_s}{R}}$$

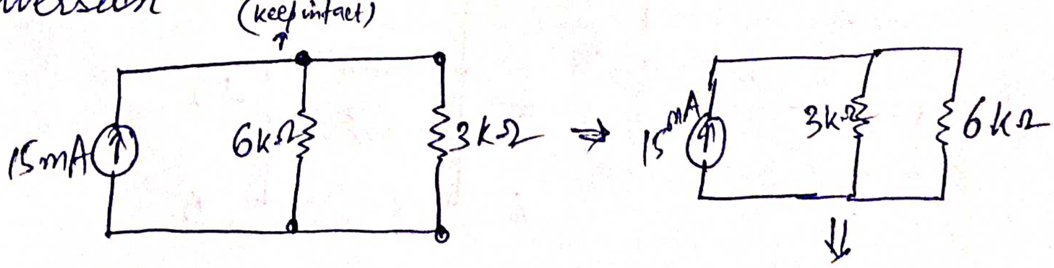


$$\boxed{V_s = I_s \times R}$$

Illustration-4

Find current in 6 kΩ resistor by converting current source to a voltage source.

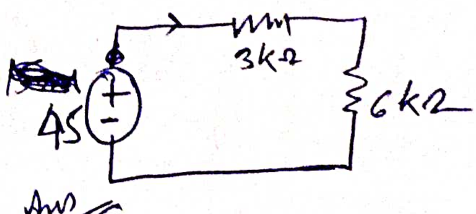
The voltage across and current through a resistance (in the converted circuit) cannot be computed if that resistance is involved in the source conversion



~~$V_s = 15mA \times R$~~ $V_s = I_s \times R$

$V_s = 15 \times 10^{-3} \times 3 \times 10^{3}$

$= \underline{\underline{45V}}$



Ans

$$I_{6k\Omega} = \frac{45}{3k\Omega + 6k\Omega}$$

$$I = \frac{45}{9\times10^{3}} = \underline{\underline{5\,mA}}$$

5mA current flows through 3kΩ resistance

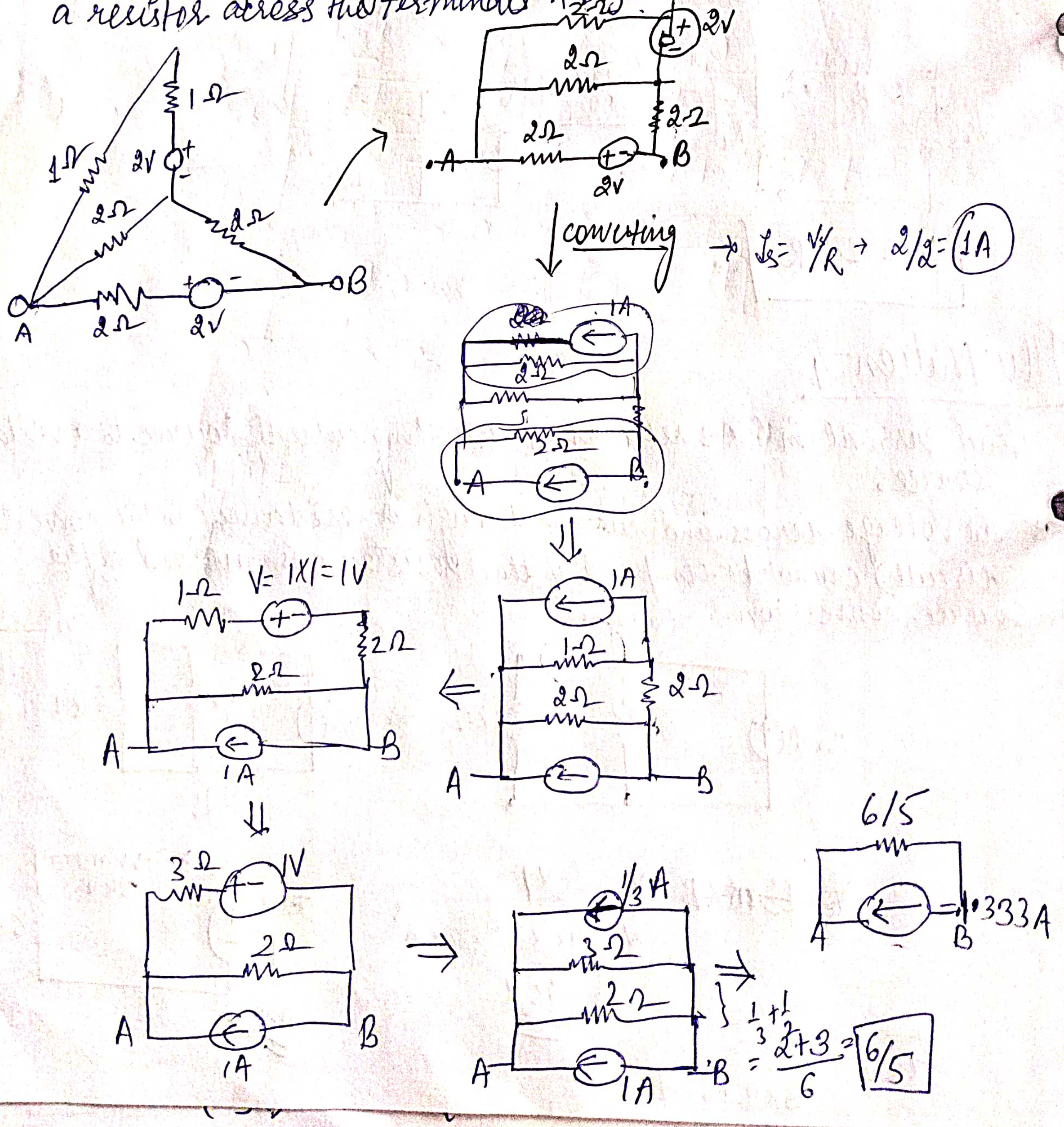
$$I_{3k\Omega} = \frac{15\,mA \times 6\,k\Omega}{9\,k\Omega}$$

$$\Rightarrow \frac{15\times10^{-3}\times6\times10^{3}}{9\times10^{3}}$$

$$= \underline{\underline{10\,mA}}$$

Illustration-5

Reduce the following circuit to a current source in parallel with a resistor across the terminals A & B.

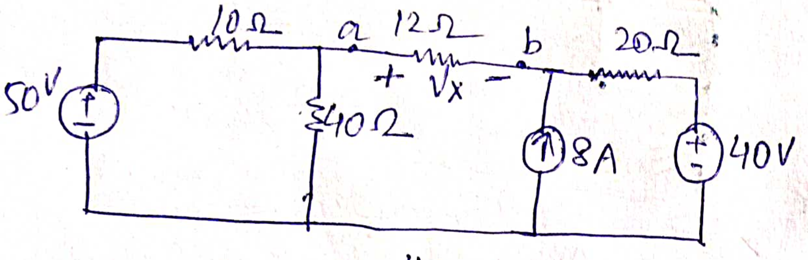


$$\rightarrow I_s = V/R \rightarrow 2/2 = 1A$$

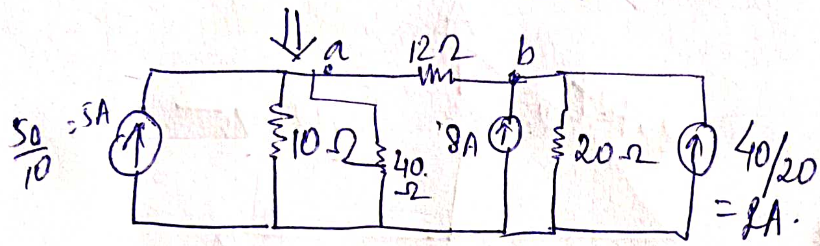
$$\frac{1}{3}+\frac{1}{2} = \frac{2+3}{6} = \boxed{6/5}$$

Illustration - 6

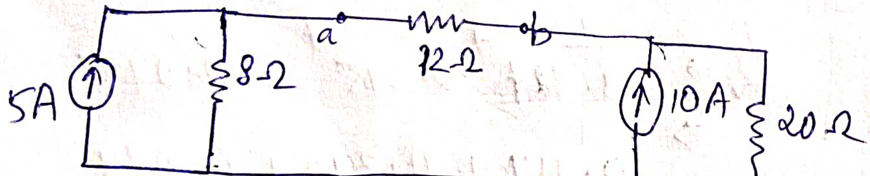
Find the voltage across 12Ω resistor (i.e. V_x) by source transformation method.



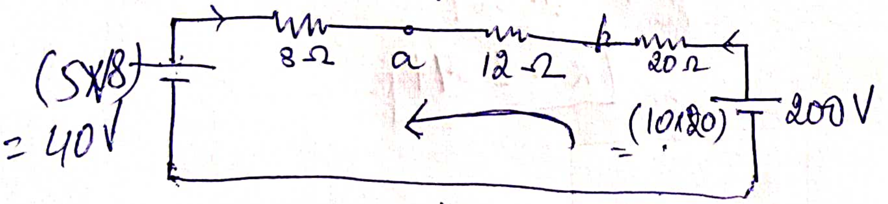
⇓



(40Ω and 10Ω in ||)



⇓



OR

$40V + 8I + 12I + 20I - 200 = 0$

↓

<u>Using KVL</u>

$+200 + (-20 \times I) - 12I - 8I - 40 = 0$

$160 - 40I = 0$

$160 = 40I$

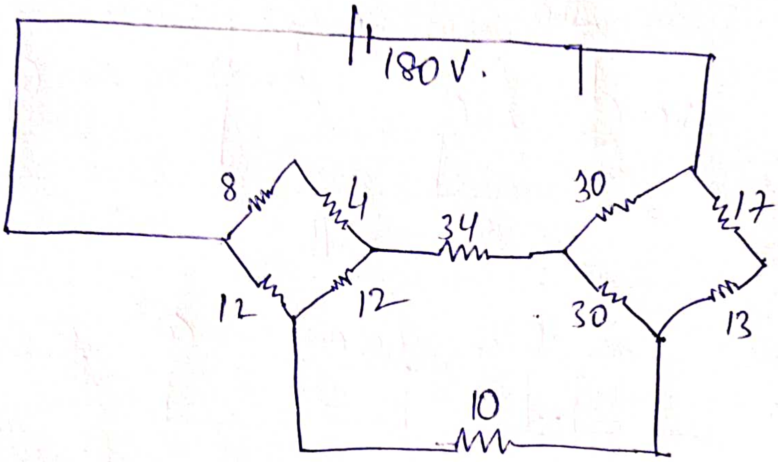
$I = \frac{160}{40} = 4A$

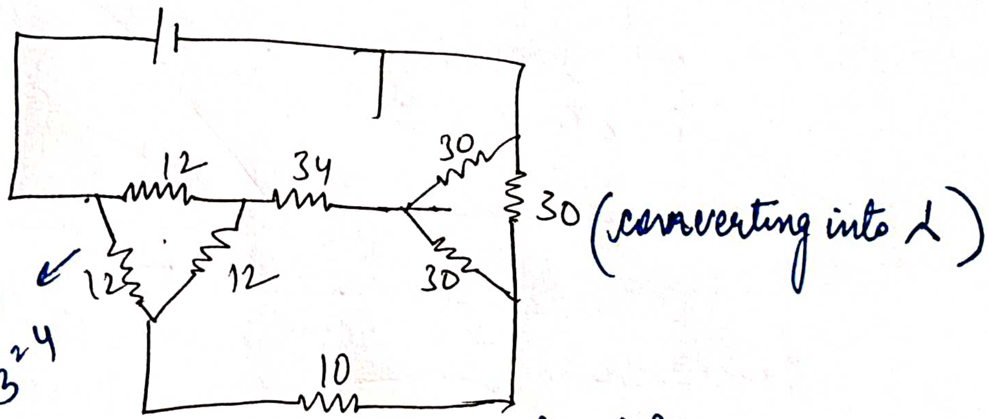
$V_{ba} = 4 \times 12 = 48$ Volts

$\therefore V_x = V_{ab} = -V_{ba} = -48$ volts

Quiz Question

Determine current flowing through 10 Ω resistor. All resistance are in Ohms.



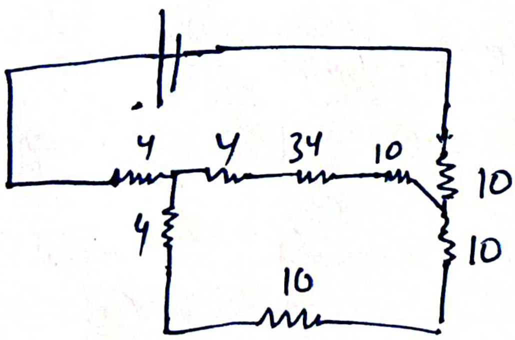


$R_\star = 12/3 = 4$

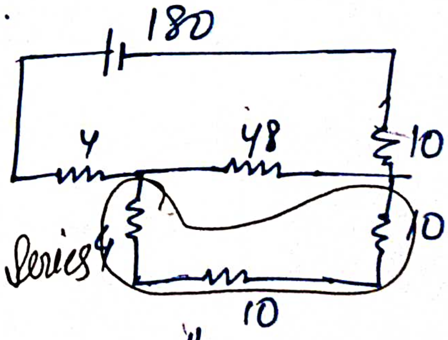
Since R_Δ is balanced.

$R_\Delta = 3R_\star$

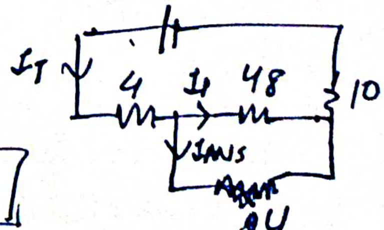
$R_\star = \frac{R_\Delta}{3}$.



$\Rightarrow$



$\Downarrow$



$$I_T = \frac{180}{4+(48 \parallel 24)+10}$$

$$I_T = \frac{180}{4+16+10} = \frac{180}{30} = \boxed{6A}$$

$$I_{ANS} = I_T \times \frac{48}{48+24} = \frac{6 \times 48}{72} \Rightarrow \boxed{4A} \text{ Ans}$$

$$\frac{1}{48}+\frac{1}{24} = \frac{1+2}{48} = \frac{48}{3} = 16$$

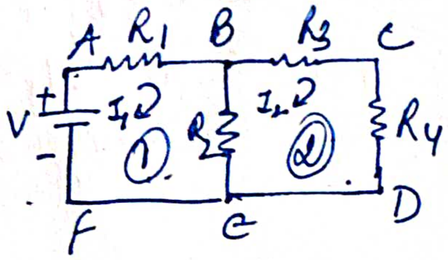
Mesh Current Analysis (network reduction technique)

(valid for planar circuit)

Mesh → A closed path for flow of current.

Kirchoff's voltage Law (KVL)

The algebraic sum of voltages in a mesh is 0.



ABEF → 1

BCDE → 2.

ABCDEF → Loop.

ABEF ⇒ $I_1R_1 + (I_1 - I_2)R_2 - V = 0$.

BCDE ⇒ $I_2R_3 + I_2R_4 + R_2(I_2 - I_1) = 0$.

⇒ $I_1R_1 + I_1R_2 - I_2R_2 - V = 0$.

⇒ $I_2R_3 + I_2R_4 + R_2I_2 - R_2I_1 = 0$.

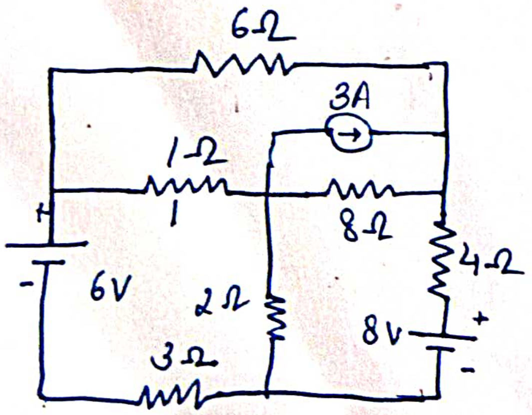
Mesh Analysis Method

(1) Transform all the current sources present in the circuit to the voltage sources.

(2) Mark different currents in all the independent meshes of the given network.

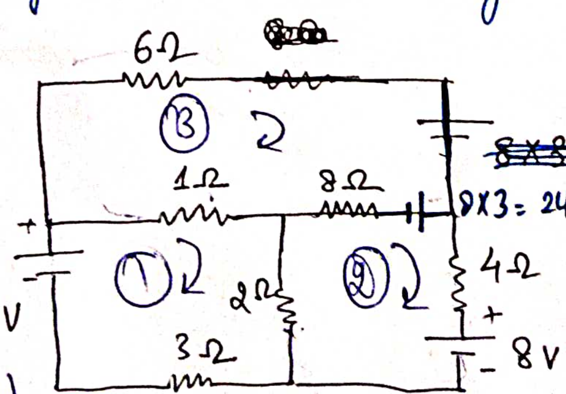
(3) Write KVL equations for these independent meshes.

(4) Solve for the currents



Determine the power drawn by 2Ω resistor using mesh current analysis.

$V = IR$



Loop1 → $6 - 3I_1 - 2(I_1 - I_2) - 1(I_1 - I_3) = 0$

Loop2 → $-2(I_2 - I_1) - 8(I_2 - I_3) - 4I_2 + 8 = 0$ $+24$

loop 3 $\rightarrow -8(I_3 - I_2) - 1(I_3 - I_1) - 6I_3 + 24 = 0$

<u>solving the equations</u>

$\rightarrow -8I_3 + 8I_2 - I_3 + I_1 - 6I_3 + 24 = 0$

$\rightarrow 6 - 3I_1 - 2I_1 + 2I_2 - I_1 + I_3 = 0$

$\rightarrow -2I_2 + 2I_1 - 8I_2 + 8I_3 - 4I_2 + 16 = 0$

$\rightarrow -15I_3 + 8I_2 + I_1 = +24$

$\rightarrow -6I_1 + I_3 + 2I_2 = -6$

$\rightarrow -14I_2 + 2I_1 + 8I_3 = +16$

~~0.99~~ $\leftarrow I_1 = x = ~~+90/77~~$

~~-0.33~~ $\leftarrow ~~I_2 = y = 214/77~~$

~~-1.74~~ $\leftarrow ~~I_3 = z = 250/77~~$

$I_1 =$

$~~15I_3 - 8I_2 - I_1 = 24~~$

$~~-I_3 - 2I_2 + 6I_1 = 6~~ \times 4$

$~~19I_3 - 25I_1 = 0~~$

$-6I_1 + 2I_2 + I_3 = -6$

$3 \times \; ~~2I_1 - 14I_2 + 8I_3 = -8~~$

$~~-6I_1 + 2I_2 + I_3 = -6~~$

$~~6I_1 - 42I_2 + 24I_3 = -24~~$

$~~-40I_2 + 25I_3 = -30~~$

$~~-8I_2 + 5I_3 = -6~~$

$I_1 = 0.99\ A$

$I_2 = 0.58\ A$

$I_3 = -1.22\ A$

Power $= I^2R$

$= (0.99 - 0.58)^2 \times 2 \; ~~(I_2 - I_1)^2 \times 2~~$

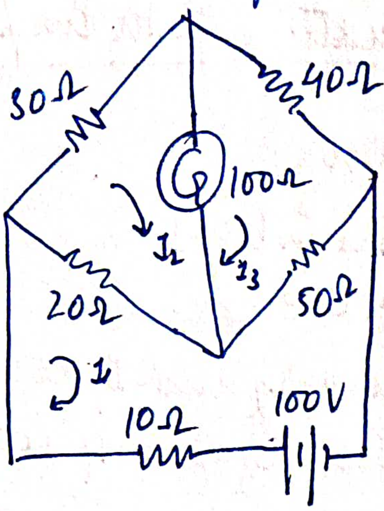
$= ~~(0.31)^2 \times 2~~$

$= ~~0.0961 \times 2~~$

$= ~~0.1922~~$ ~~Watt~~

<u>0.324 Watts</u>

Q2) Determine the current through the galvanometer "G".



KVC Equations

For ① → $-10I_1 - 20(I_1-I_2) - 50(I_1-I_3) + 100 = 0$

For ② → $20(I_2-I_1) + 30I_2 + 100(I_2-I_3) = 0$.

For ③ → $40I_3 + 50(I_3-I_1) + 100(I_3-I_2) = 0$.

For 1 → $-10I_1 - 20I_1 + 20I_2 - 50I_1 + 50I_3 + 100 = 0$

For 2 → $20I_2 - 20I_1 + 30I_2 + 100I_2 - 100I_3 = 0$

For 3 → $40I_3 + 50I_3 - 50I_1 + 100I_3 - 100I_2 = 0$.

① → $-80I_1 + 20I_2 + 50I_3 = -100$

② → $150I_2 - 20I_1 - 100I_3 = 0$

③ → $190I_3 - 50I_1 - 100I_2 = 0$

$x = 2.23 = I_1$

$y = 1.06 = I_2$

$z = 1.14 = I_3$

Current through Ⓖ

$100(I_3 - I_2)$

$\Rightarrow \cancel{100(1.14-1.06)}$ $\cancel{V=IR}$

$I_G \Rightarrow 1.14 - 1.06$ $\cancel{I = V/R}$

$= \underline{0.08A}$

direction ↑ coz I_3 is greater

Q3b How to write network equation with inspection

→ Refering to the previous question

loop 1

I_1 ⇒ sum of all resistors in loop 1

⇒ $20+50+10 = 80$.

I_2 → Resistor between I_2 and I_1 loop → 20

I_3 → Resistor between I_3 and I_1 loop → 50

∴ Equation = $80I_1 - 20I_2 - 50I_3 = 100$. (only I_1 should be +ve.)

loop 2

I_2 = sum of all resistors in loop 2

→ Ω $150 = 30 + 20 + 100$

I_1 = Resistor between I_1 and I_2 = 20Ω

I_3 = Resistor between I_2 and I_3 = 100Ω (only I_2 should be +ve)

∴ Equation = $-20I_1 + 150I_2 - 100I_3 = 0$.

loop 3

I_3 = sum of all resistors in loop 3

⇒ $40+100+50 = 190\Omega$. (only I_3 should be +ve)

I_1 = resistor between I_1 and I_3 = 50Ω.

I_2 = resistor between I_2 and I_3 = 100Ω

$$190I_3 - 50I_1 - 100I_2 = 0.$$

Polarity of V

→ When current enters (-)ve terminal → V is (+ve)

→ When currents leaves (+)ve terminal → V is -ve

$$\begin{bmatrix} 80 & -20 & -50 \\ -20 & 150 & -100 \\ -50 & -100 & 190 \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \\ i_3 \end{bmatrix} = \begin{bmatrix} 100 \\ 0 \\ 0 \end{bmatrix}$$

Q4) Realize the network defined by mesh current equations given below.

$$\begin{bmatrix} 30 & -20 & 0 \\ -20 & 50 & -20 \\ 0 & -20 & 20 \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \\ i_3 \end{bmatrix} = \begin{bmatrix} 10 \\ 0 \\ -20 \end{bmatrix}$$

Ans