Module - 1 : DC Circuit Analysis

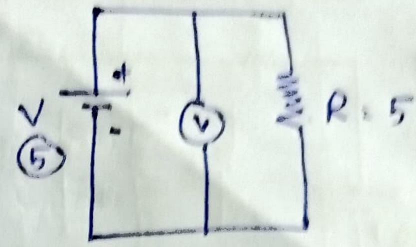
Ohm's Law :-

Current is directly proportional to voltage (in a DC circuit).

Mathematically,

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

Depending upon the question



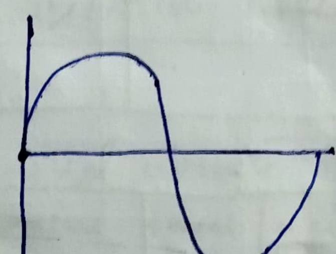
$V = IR$

V	I
5	1
7	1.4
10	2
15	3

As we increase the voltage, the current increases and vice-versa.

NOTE :-

AC Representation :



$f = 50 Hz$

$T = \frac{1}{f} = \frac{1}{50}$

$T = 0.02 s$

Reason : Dimming of light isn't observed because of such a small time interval.

Series and Parallel Circuits :-

Series : $R_{eq} = R_1 + R_2 + R_3 + \dots + R_n$ (n no. of resistors)

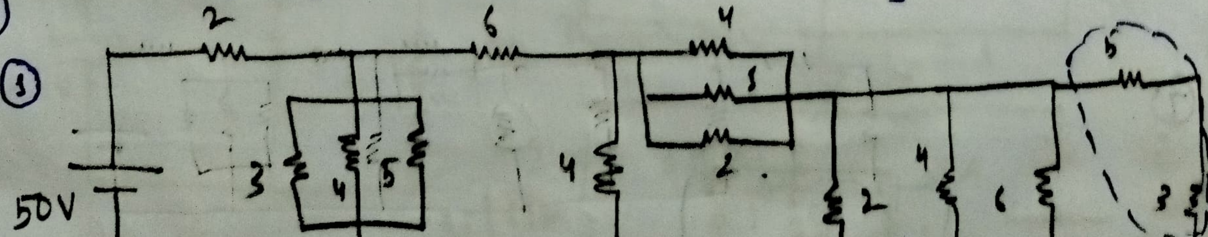
Parallel : $\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \dots + R_n$ (n no. of resistors)

[Reciprocal of result]

* for 2 resistors in Parallel :-

$R_{eq} = \frac{R_1 R_2}{R_1 + R_2}$ [R_{eq} : Equivalent Resistance]

a)



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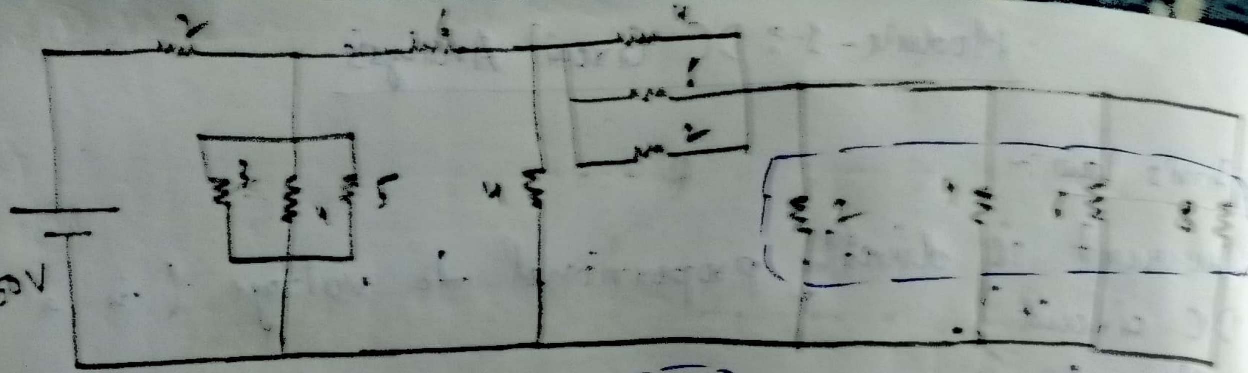

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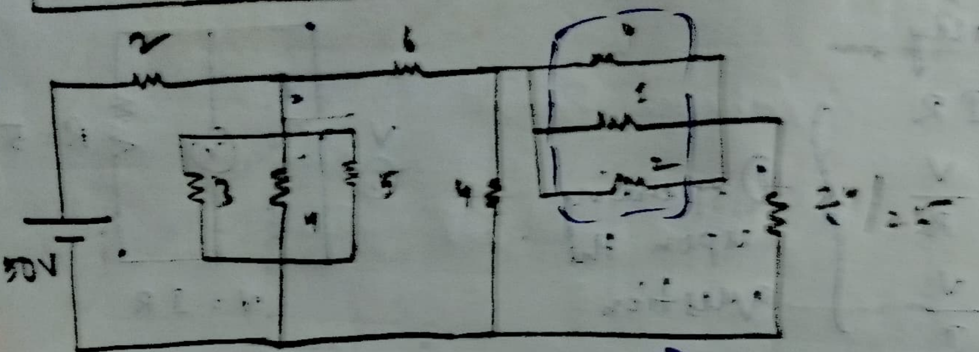

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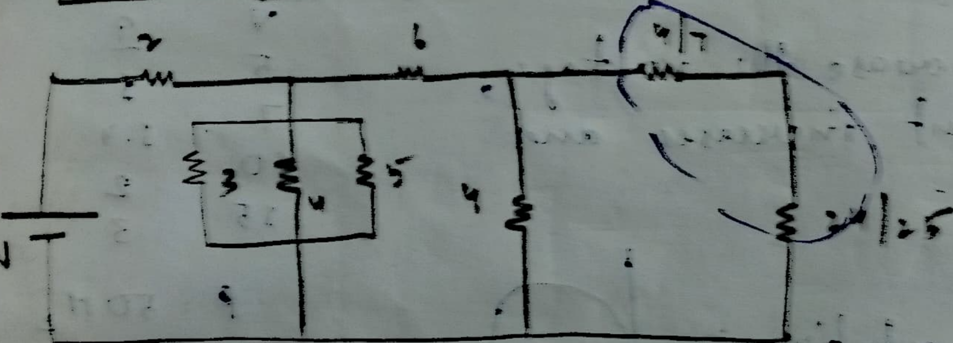

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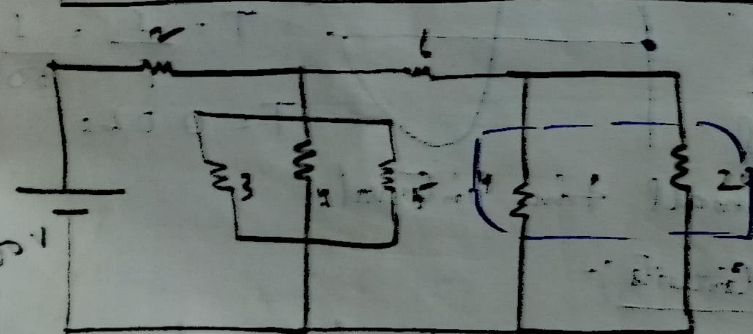

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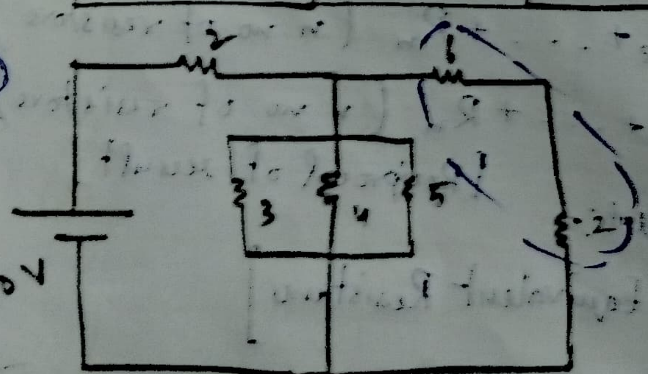

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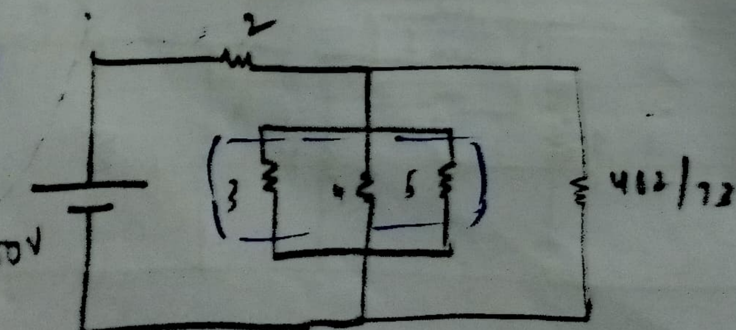

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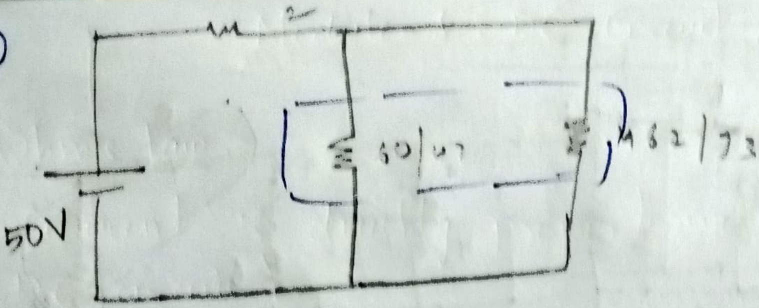

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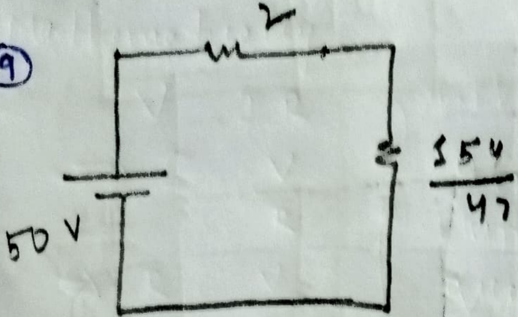

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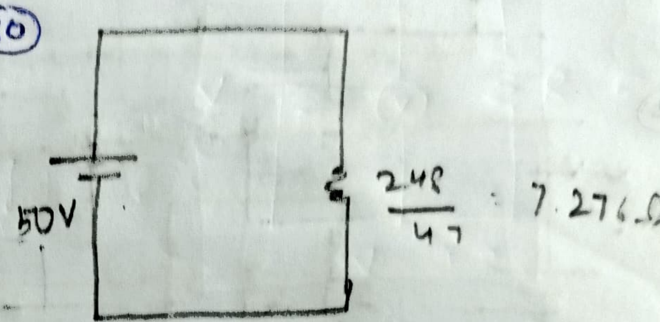


$V = 50V$; $I = ?$ $\quad V = IR$

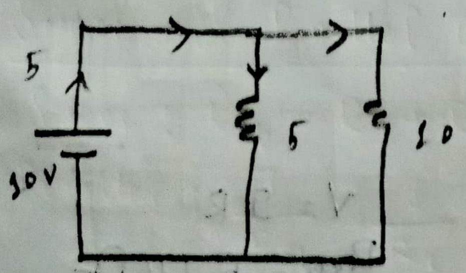
$R_{eq} = 7.276\,\Omega$ $\quad I = \frac{V}{R} = \frac{50}{7.276} = 6.87\,A$

Current And Voltage Division Rule :-

Current Division Rule :-

Applicable for only parallel circuits as current at every point / branch remains same / constant in case of series.

Maximum no. of resistors required = 2.

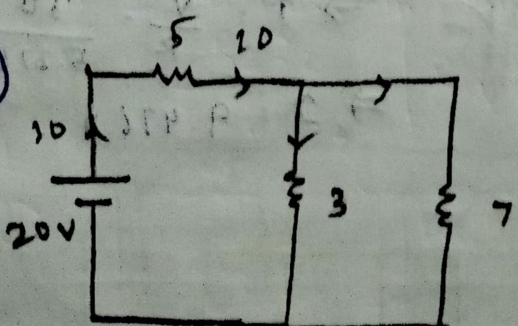


$$I_R = I_T \times \frac{\text{Oppo. resistance}}{\text{Total resistance}}$$

$$I_{10} = 5 \times \frac{5}{15} = \frac{5}{3} \simeq 1.67\,A$$

$$I_5 = 5 \times \frac{10}{15} = \frac{10}{3} \simeq 3.33\,A$$

q)



$I_5 = 10A$ (no branch)

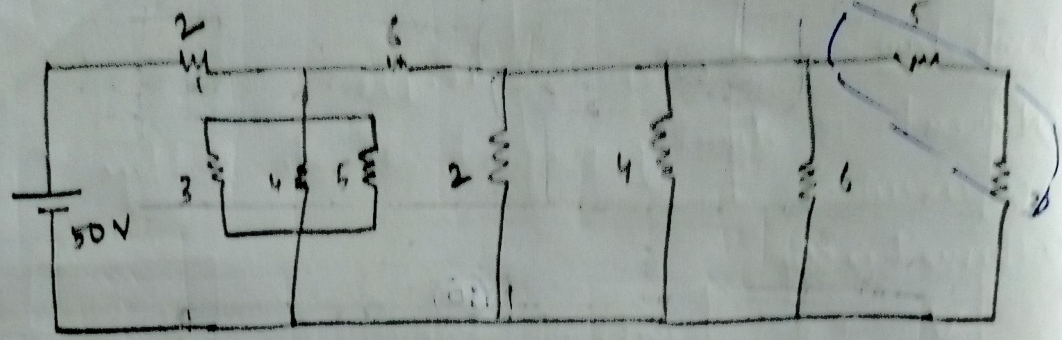
$$I_3 = 10 \times \frac{7}{10} = 7\,A$$

$$I_7 = 10 \times \frac{3}{10} = 3\,A.$$

H.W 1

a)

1



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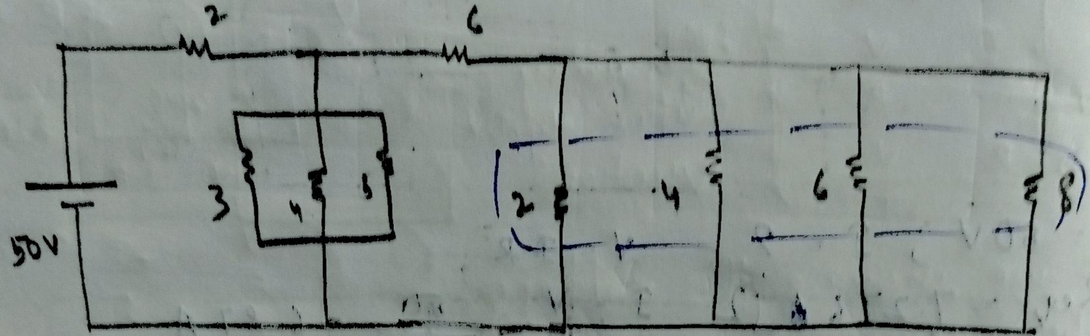

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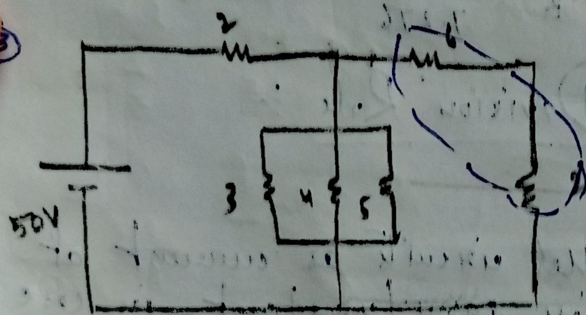

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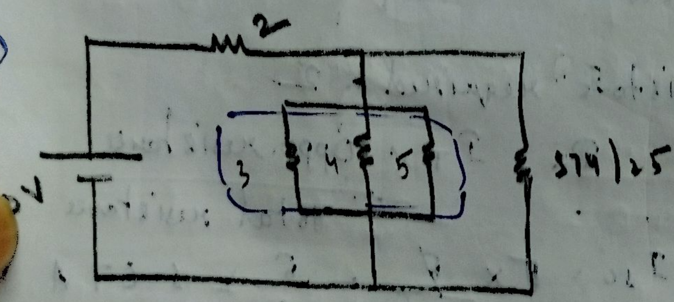

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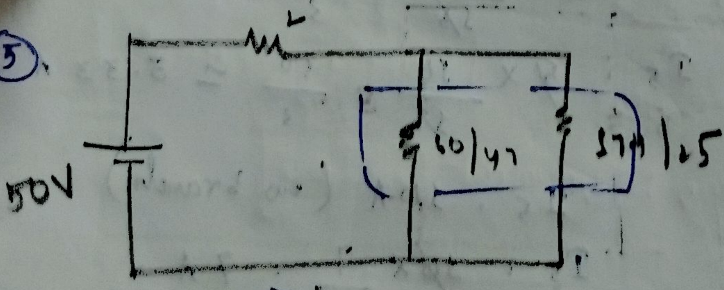


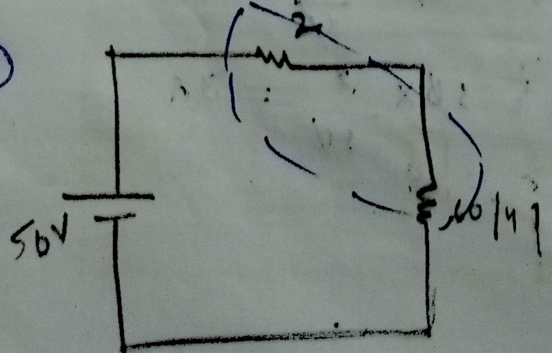
$V = IR$

$R_{eq} = 5.276\,\Omega$

$\Rightarrow I = \frac{V}{R} = \frac{50}{5.276}$

$\Rightarrow I = 9.476\,A$

6



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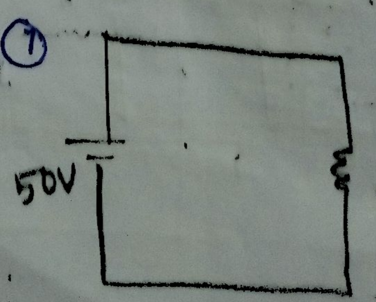
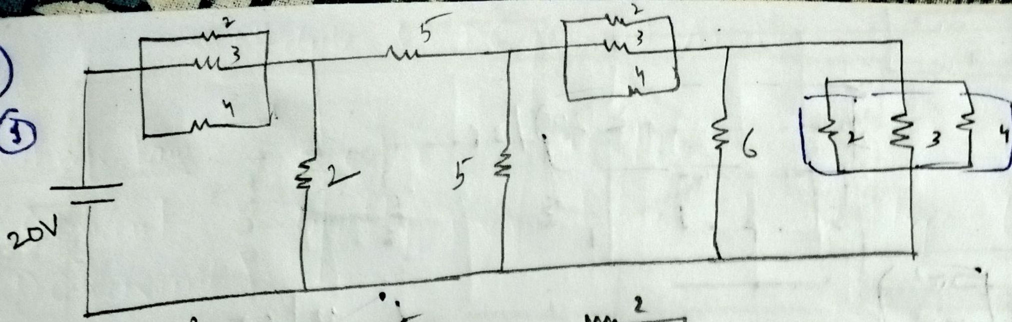


$554/47$

$= 5.276\,\Omega$

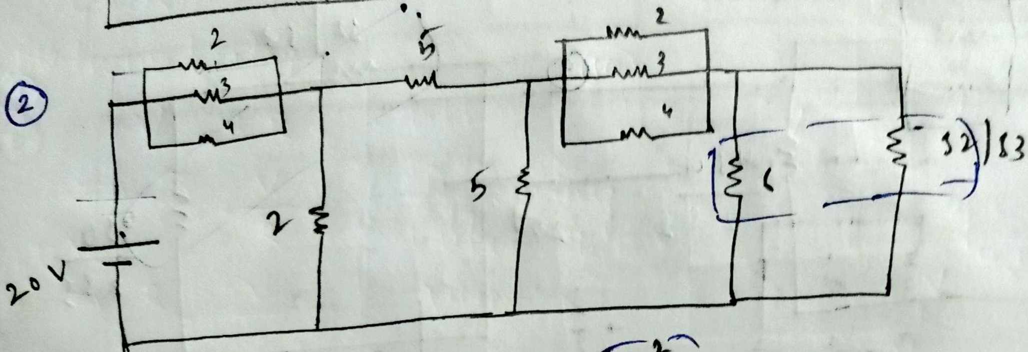
9)

①



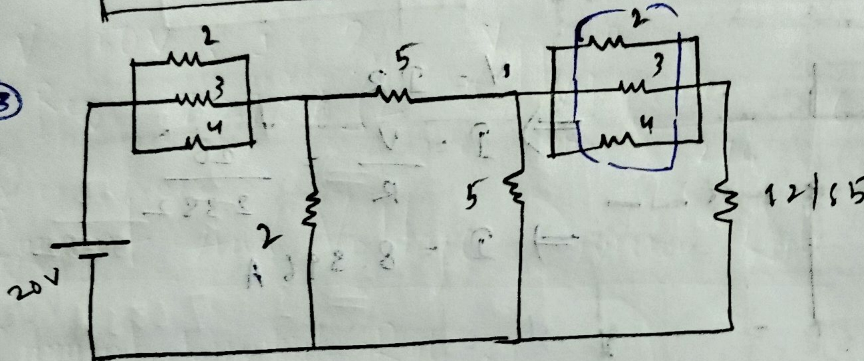
20V
2
3
4
5
2
5
2
3
4
6
2
3
4

②



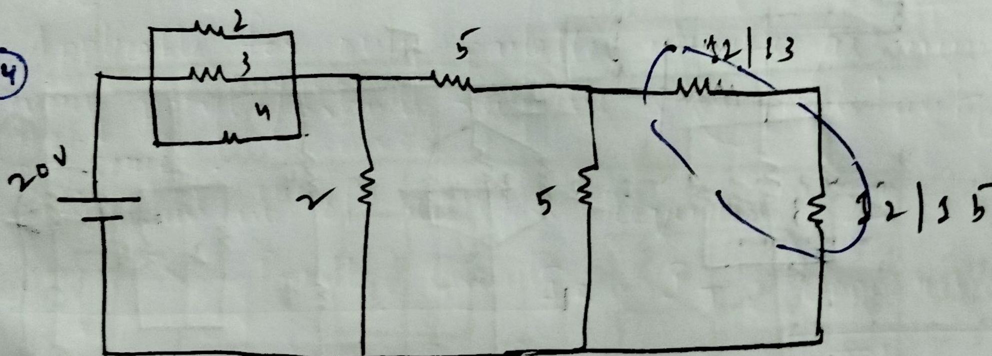
20V
2
3
4
5
2
5
2
3
4
6
12/13

③



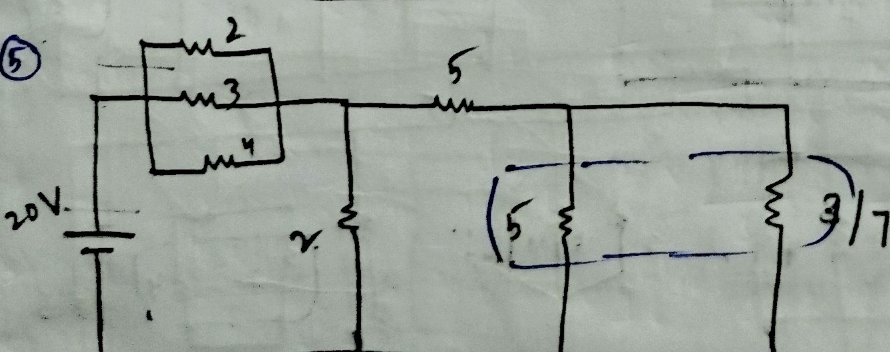
20V
2
3
4
5
2
5
2
3
4
12/15

④



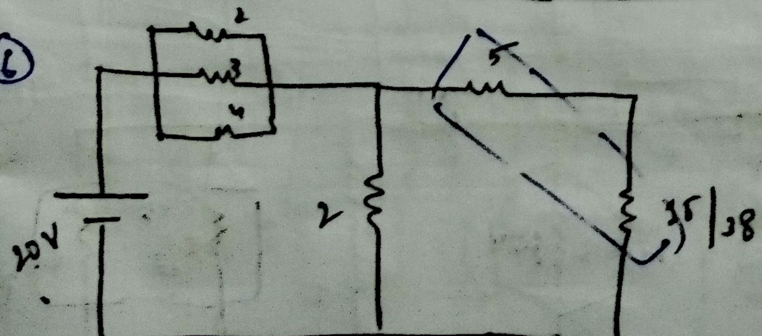
20V
2
3
4
5
2
5
12/13
12/15

⑤



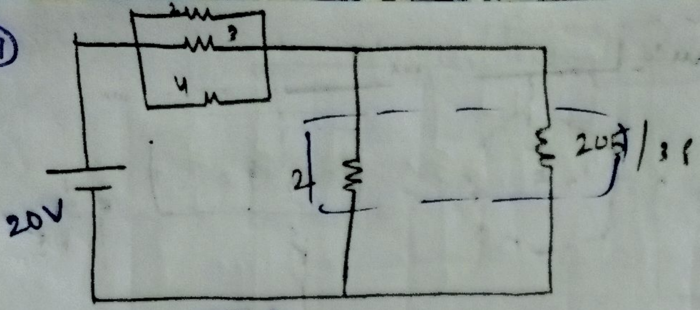
20V.
2
3
4
5
2
5
3/7

⑥



20V
2
3
4
5
2
35/38

7



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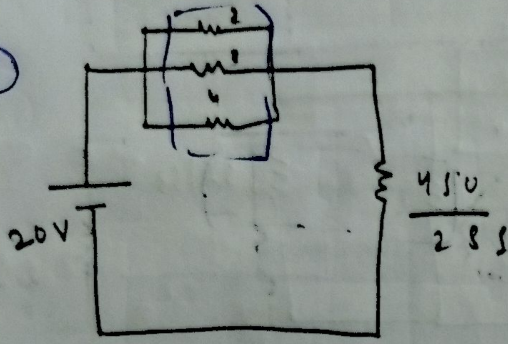

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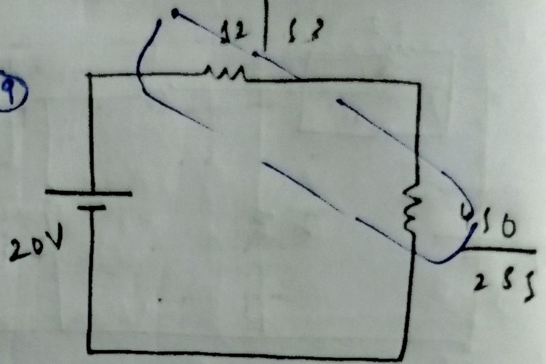

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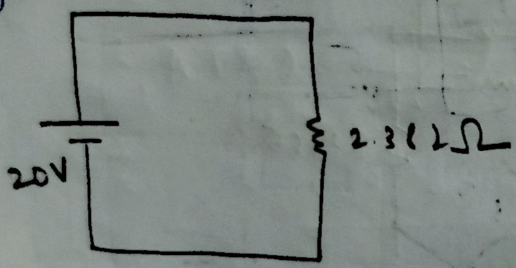


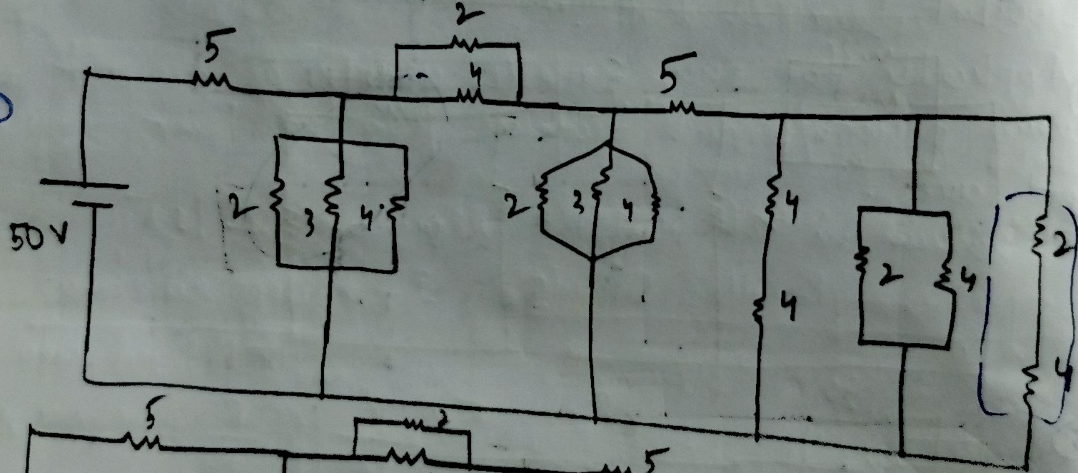
$V = IR$

$\Rightarrow I = \frac{V}{R} = \frac{20}{2.382}$

$\Rightarrow I = 8.396$ A

9)

1



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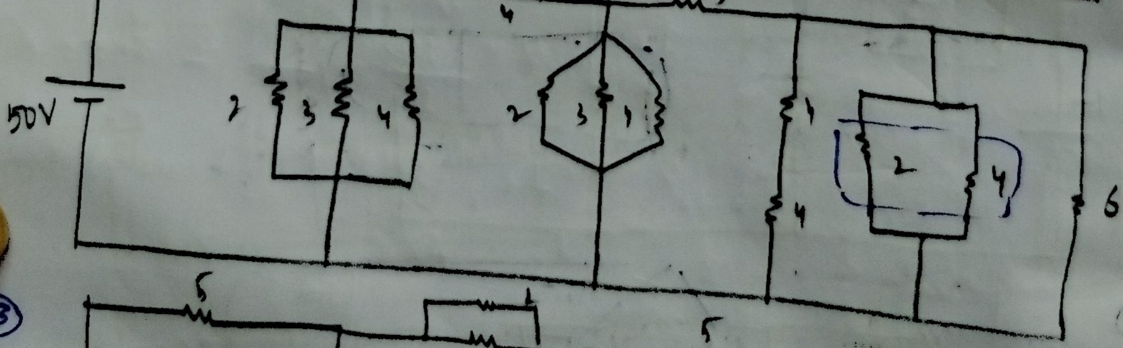

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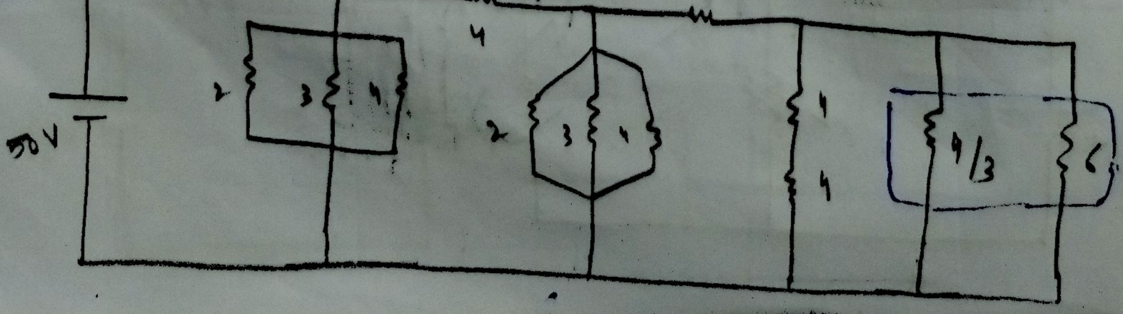

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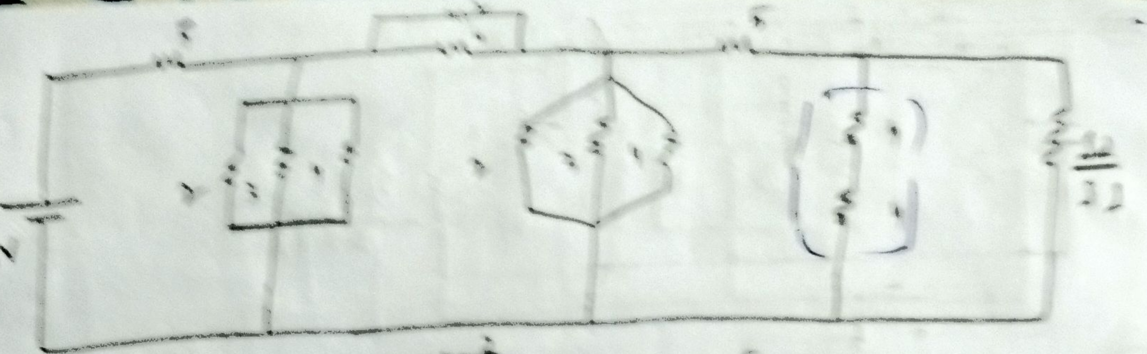

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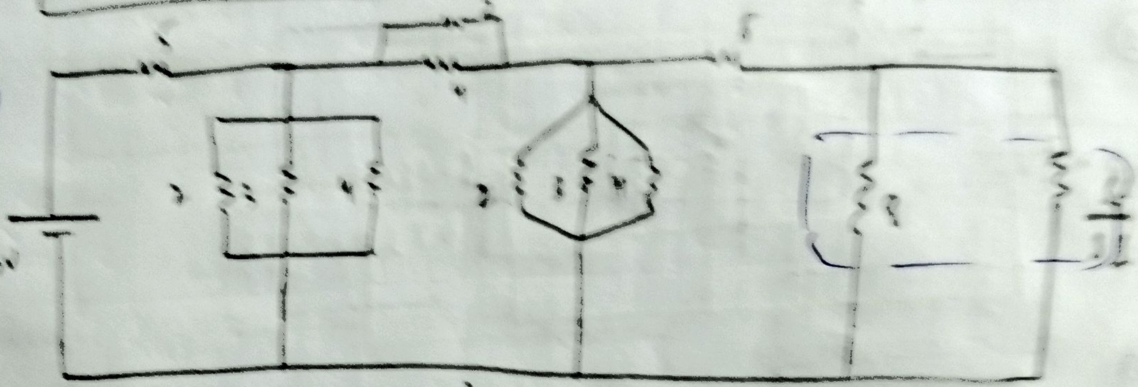

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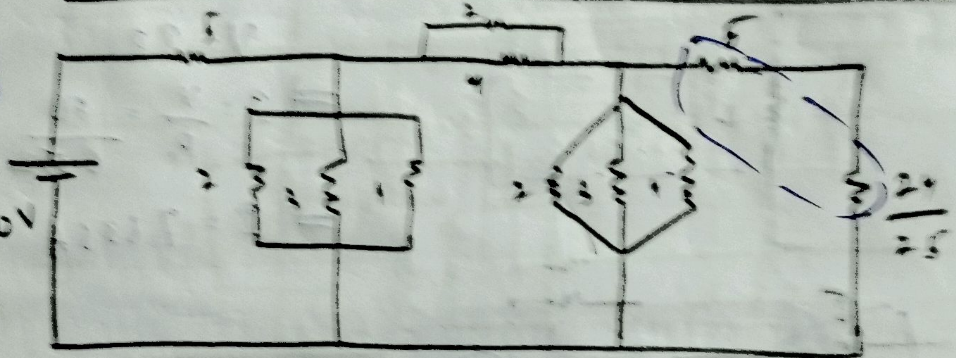

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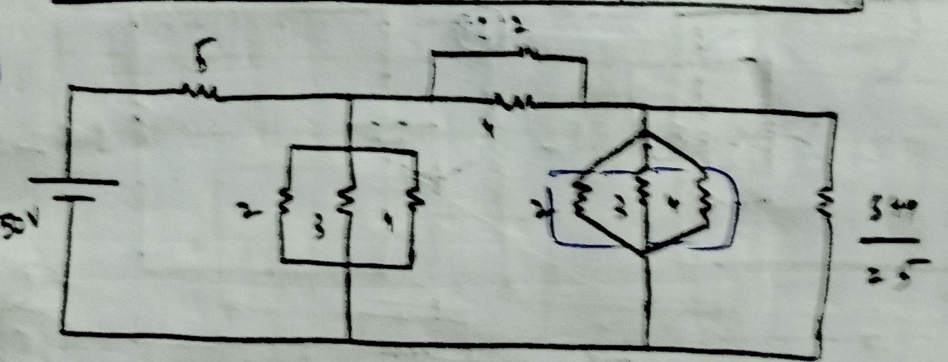

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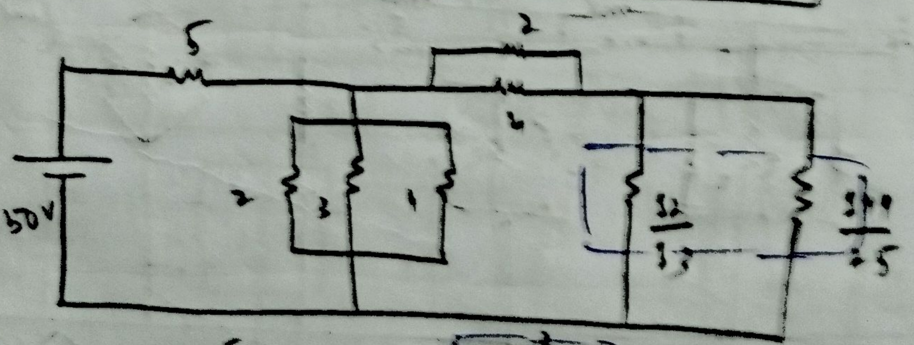

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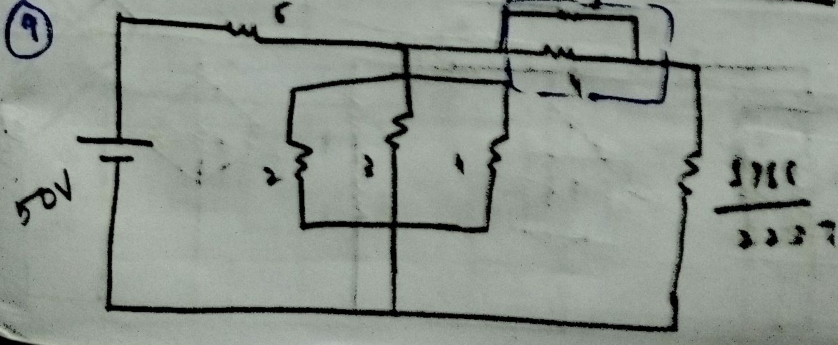

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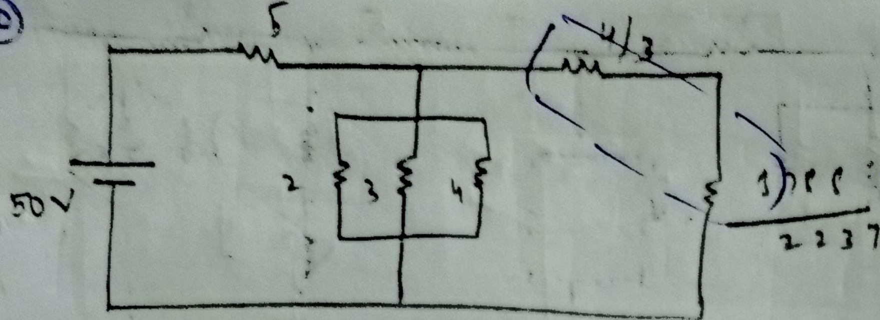

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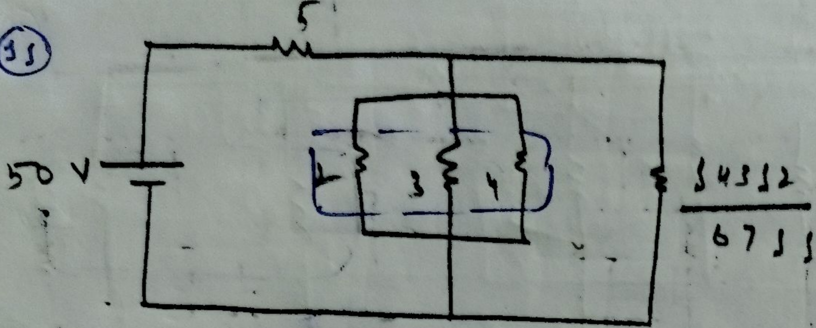

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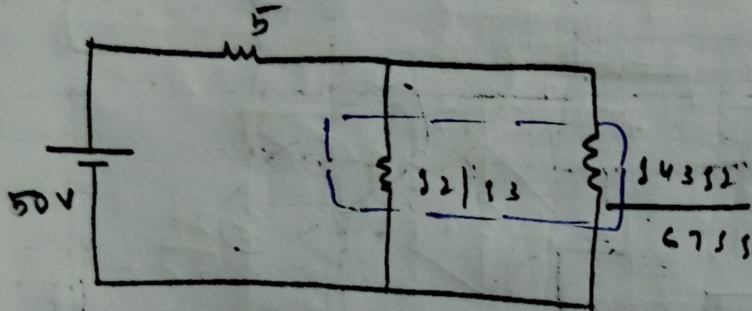
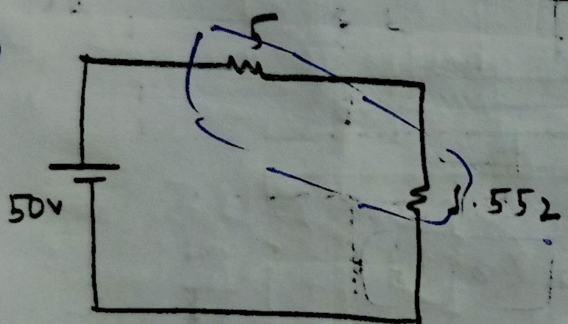


$V = IR$

$\Rightarrow I = \frac{V}{R} = \frac{50}{6.552}$

$\Rightarrow I = 7.631\,A$

(13)



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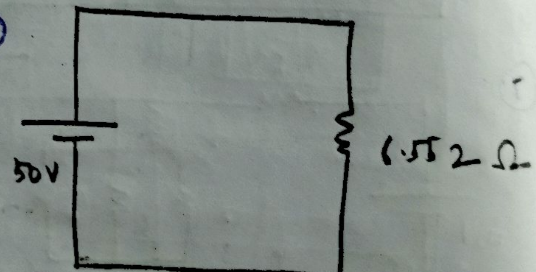

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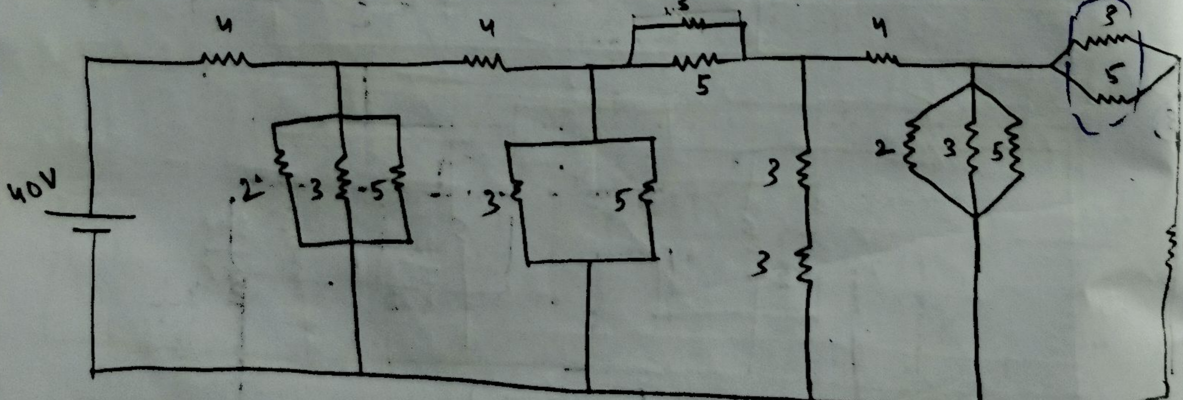

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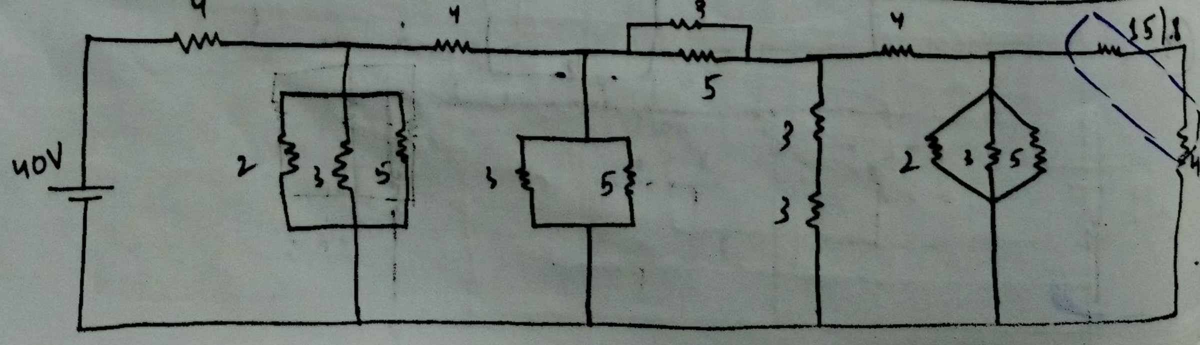

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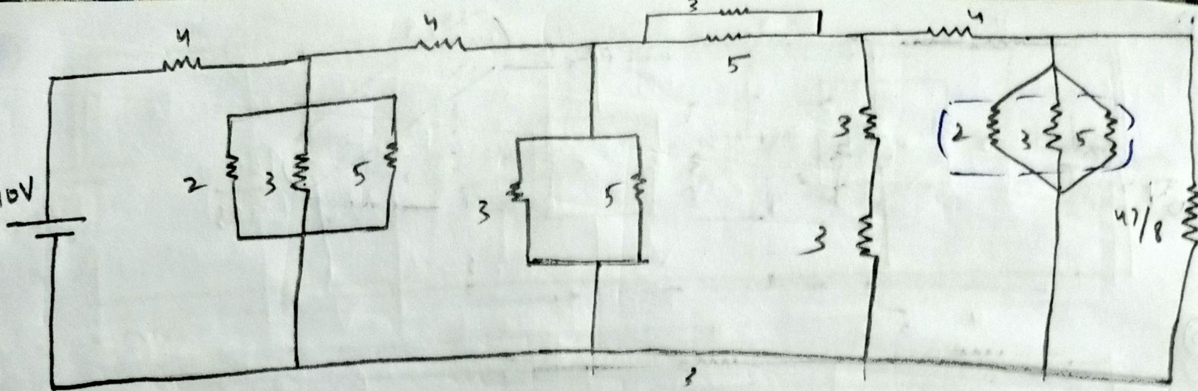
40V
4
4
3
5
4
2
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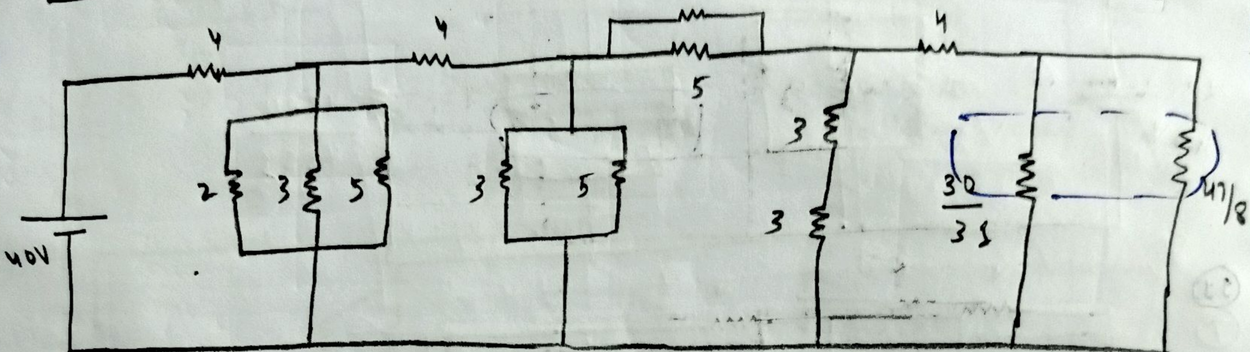
3
5
3
3
2
3
5
47/8

4


40V
4
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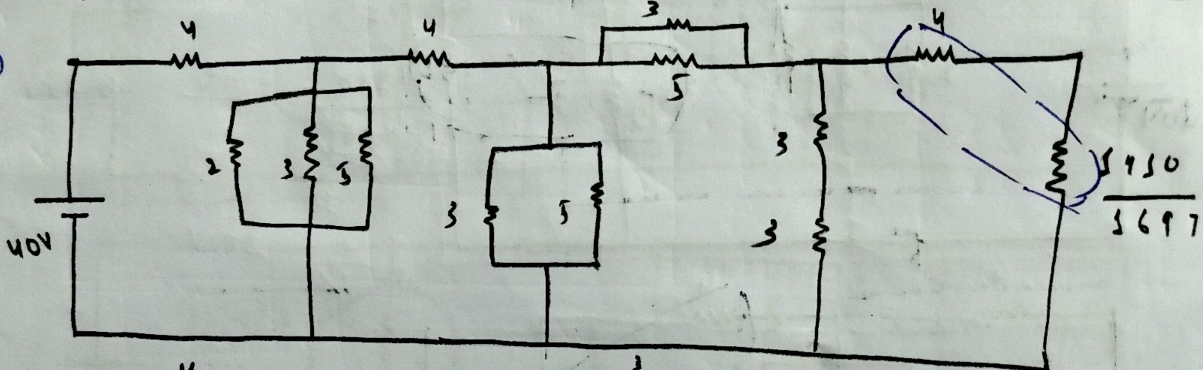
30/31
47/8

5


40V
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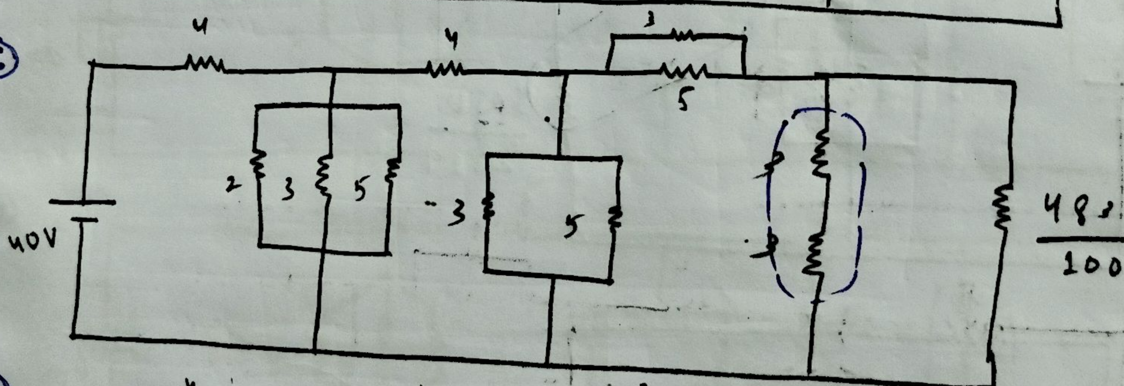
3
5430/5697

6


40V
4
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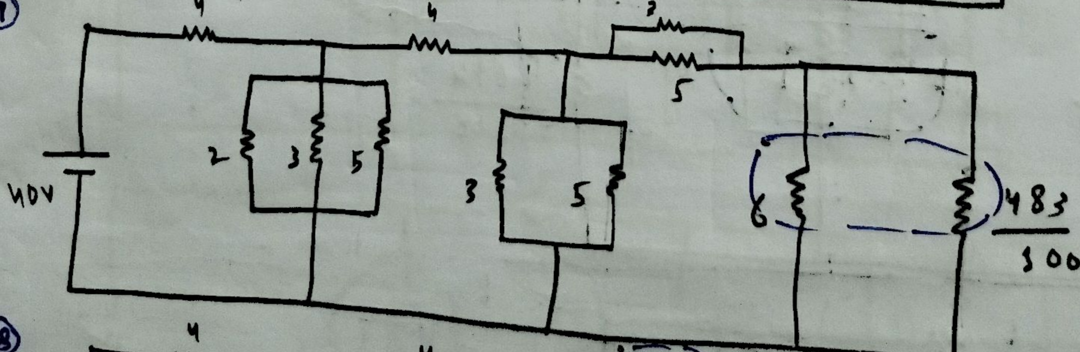
2
3
5
3
5
483/100

7


40V
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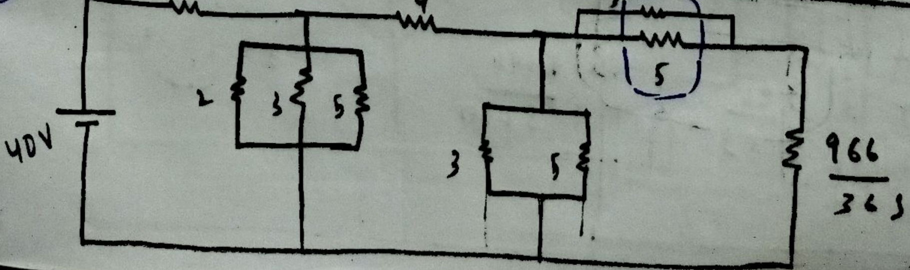
483/100

8


40V
4
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3
5
3
5
966/363

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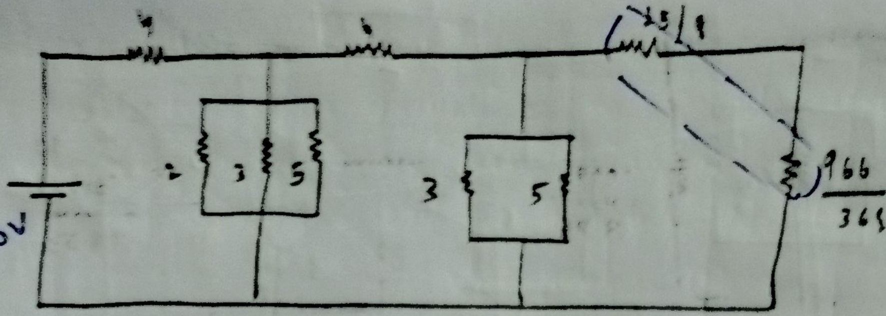

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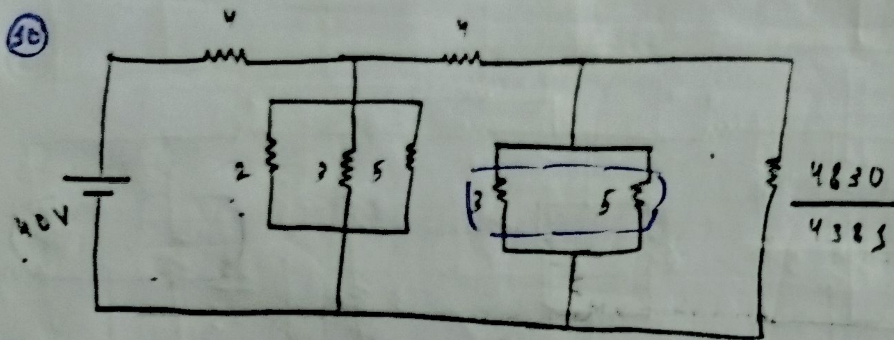

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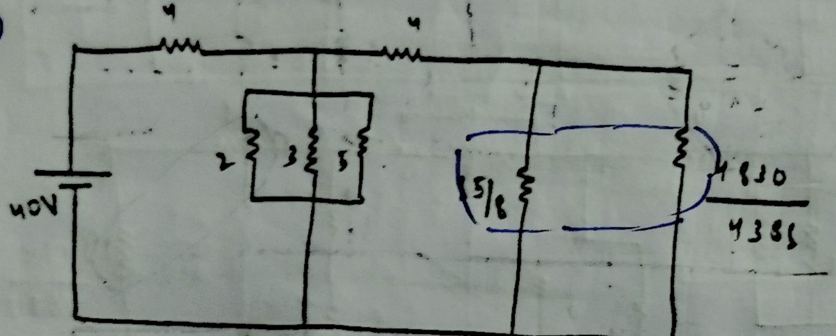

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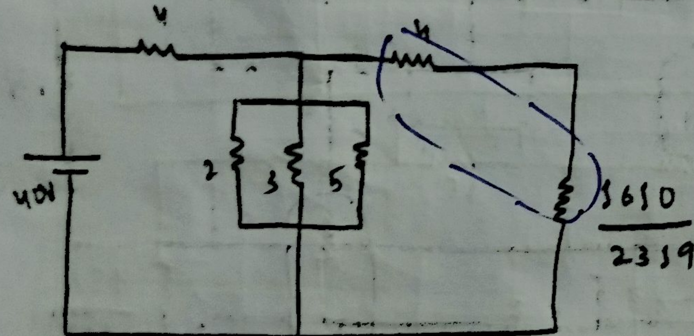

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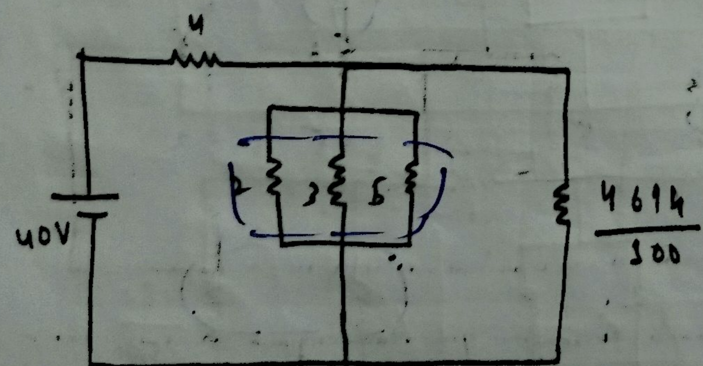

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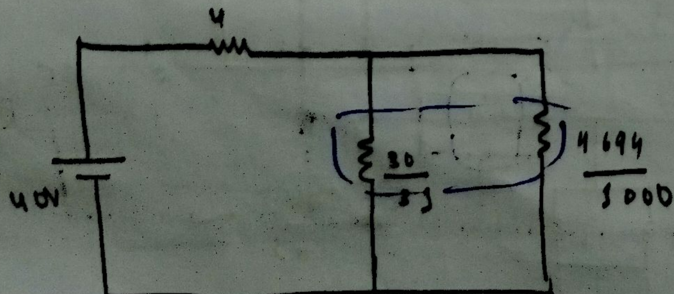

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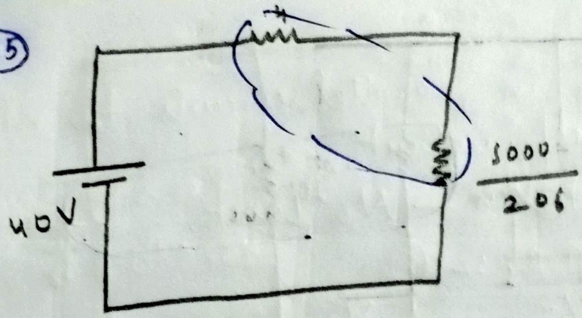

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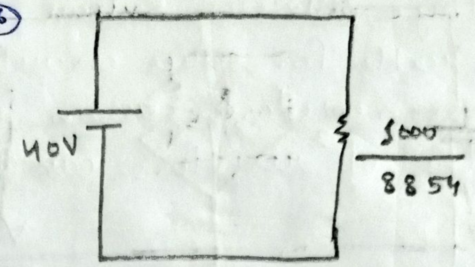


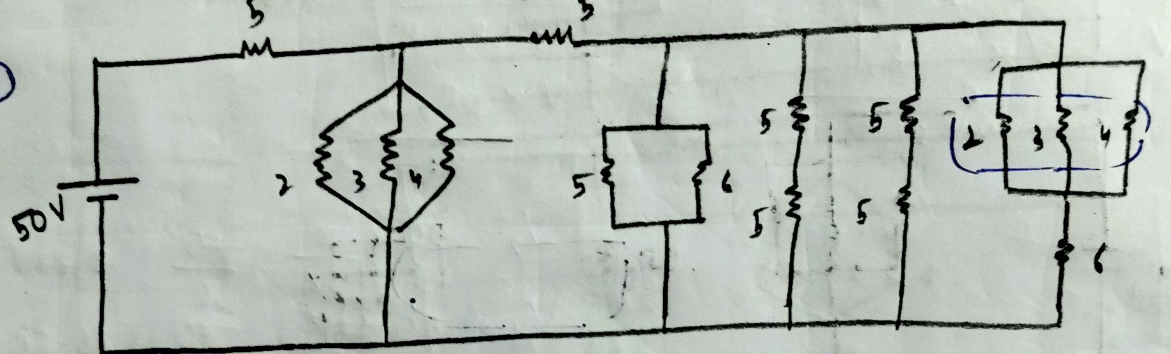
$V = 40V$

$R_{eq} = \frac{5000}{8854}\,\Omega$

$V = IR \Rightarrow I = \frac{V}{R} = \frac{4\cancel{0} \times 8854}{\cancel{5000}\ 25} = 354.16\ A$ (mathematically incorrect)

a)

(1)



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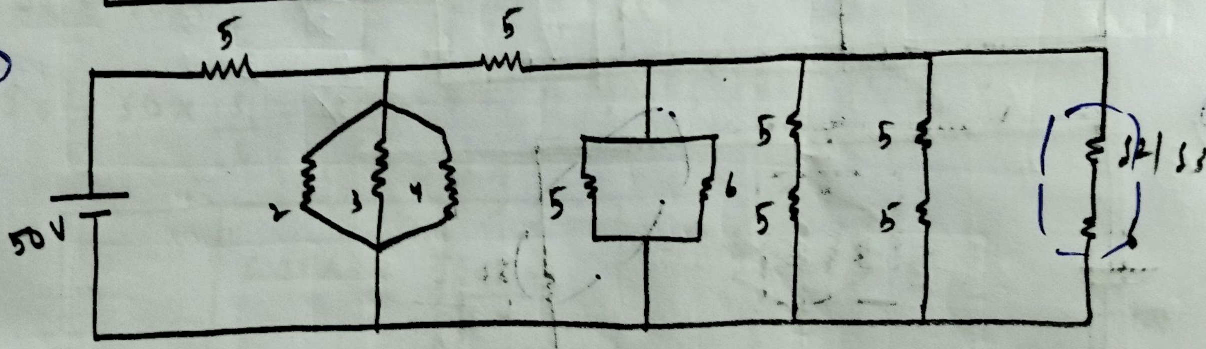
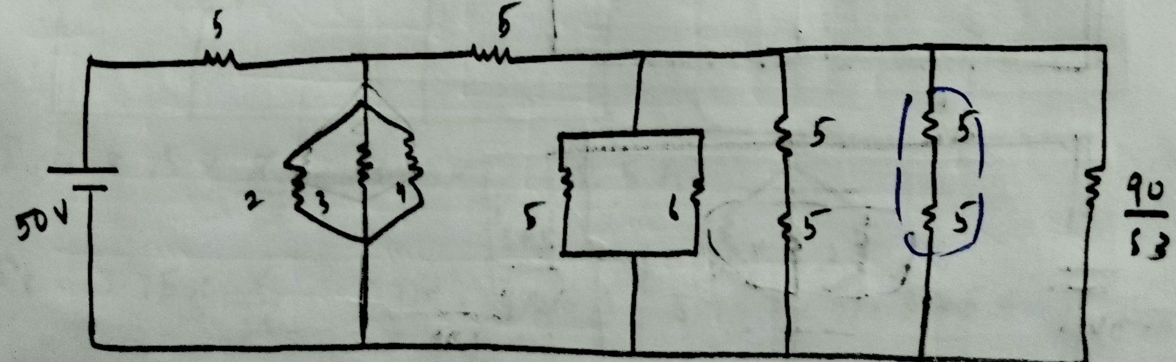
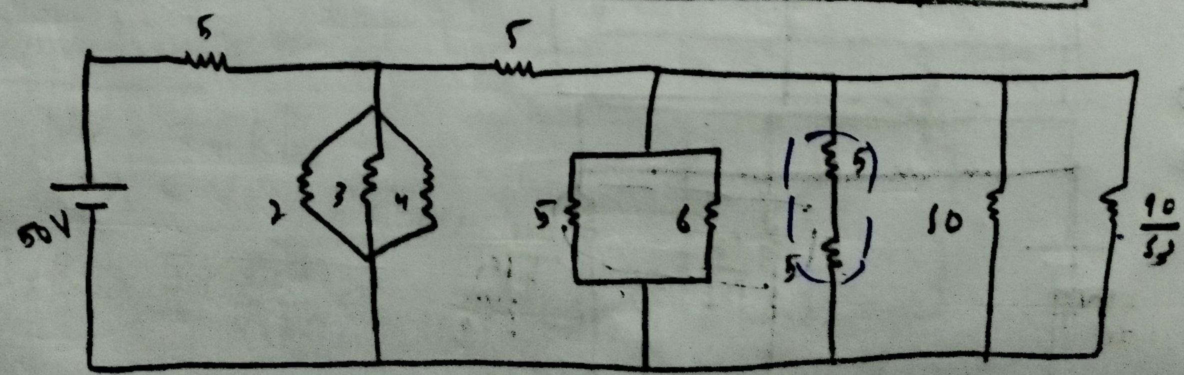


(3)



(4)



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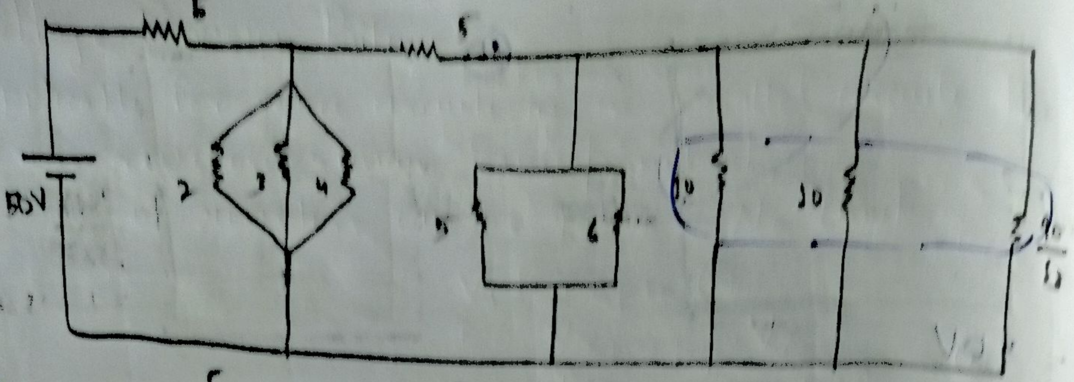

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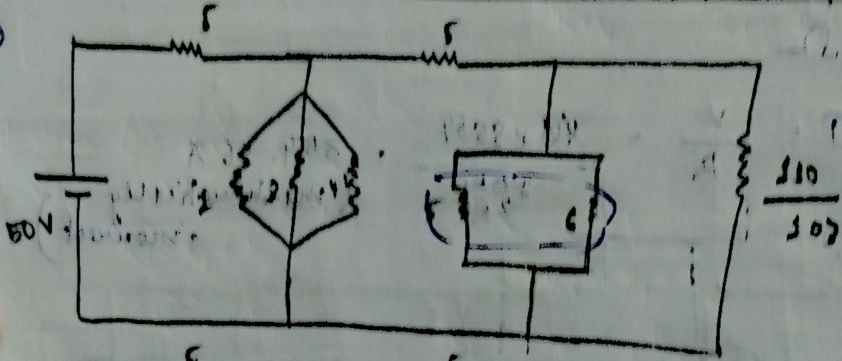

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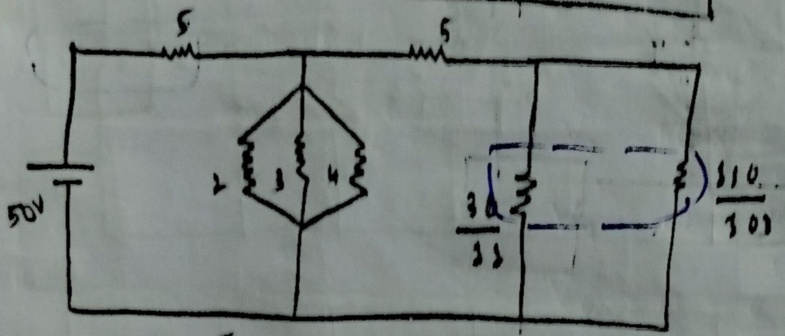
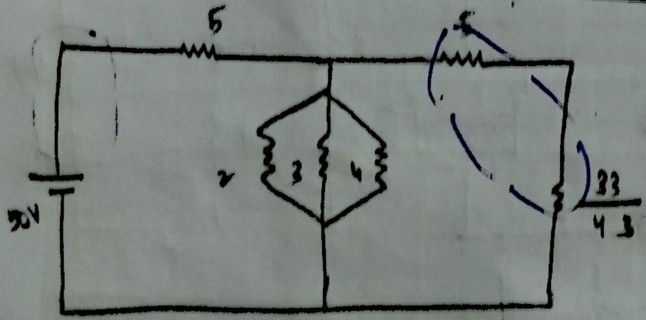
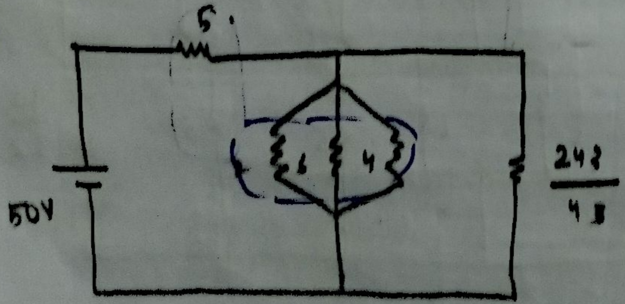


(8)



(9)



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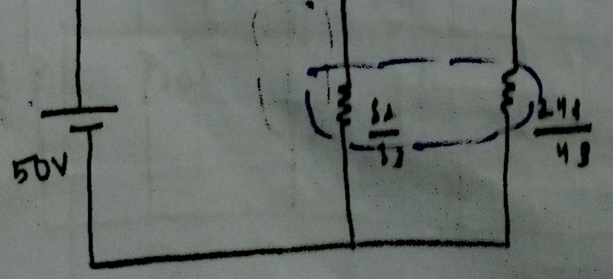

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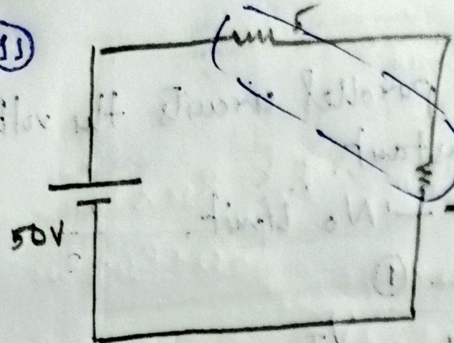
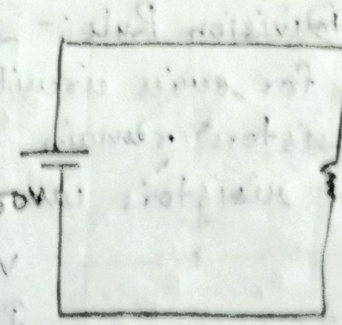


$\frac{972}{1225}$

(12)



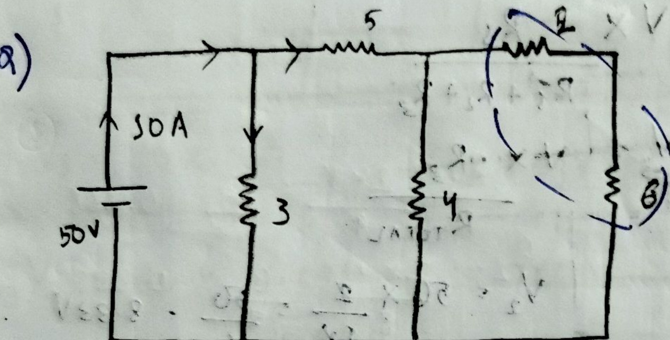
$\frac{7093}{1225} = 5.793\,\Omega$

$V = 50V$

$R_{eq} = 5.793\,\Omega$

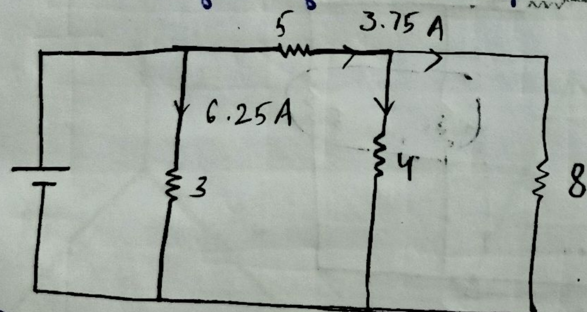
$V = IR \Rightarrow I = \frac{V}{R} = \frac{50}{5.793} = 8.631\,A$

9)



$I_3 = 10 \times \frac{5}{8} = \frac{50}{8} = 6.25\,A$

$I_5 = 10 \times \frac{3}{8} = \frac{30}{8} = 3.75\,A \;\Big|\; 10 - 6.25 = 3.75\,A$



$I_4 = 3.75 \times \frac{\cancel{8}}{\cancel{12}} = 3.75 \times \frac{2}{3} = 2.5\,A$

$I_8 = 3.75 \times \frac{\cancel{4}}{\cancel{12}} = \frac{3.75}{3} = 1.25\,A \;\Big|\; 3.75 - 2.5 = 1.25\,A$

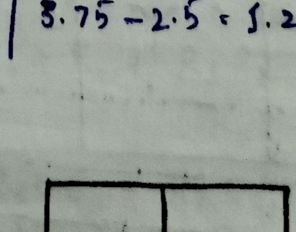
<u>Derivation :-</u>

$V_T = I_T R_{eq}$

$V_1 = V_T = I_T R_{eq}$

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

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

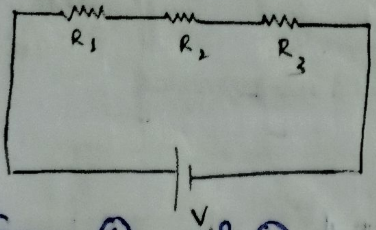


$I_0 = I_T \times \frac{\text{Oppo. Resistance}}{\text{Total Resistance}}$

Voltage Division Rule :-

Applicable for series circuits as in parallel circuits the voltage across resistors remain same / constant.

'n' no. of resistors can be taken — No Limit.



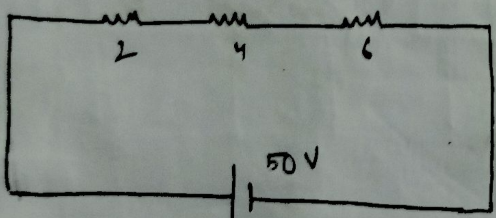
$V_1 = I R_1$ — (1)

$I = \frac{V_T}{R_{eq}} = \frac{V_T}{R_1 + R_2 + R_3}$ — (2)

From (1) and (2),

$V_1 = \frac{V_T}{R_1+R_2+R_3} \times R_1 = V \times \frac{R_1}{R_1+R_2+R_3}$

$V_2 = V \times \frac{R_2}{R_1+R_2+R_3}$; $V_3 = V \times \frac{R_3}{R_{TOTAL}}$

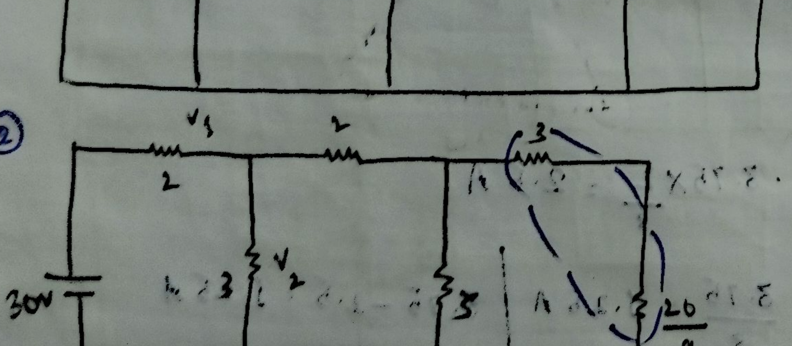


$V_2 = 50 \times \frac{\cancel{2}}{\cancel{12}} = \frac{50}{6} = 8.33V$

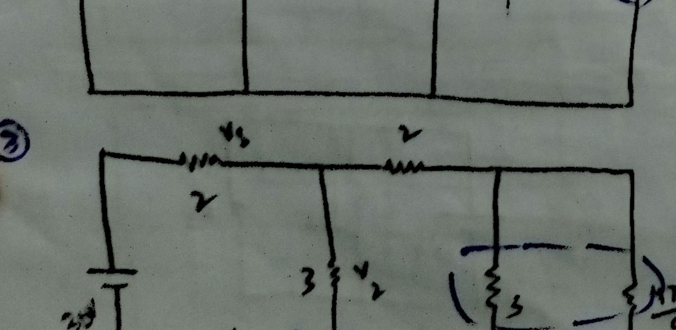
$V_4 = 50 \times \frac{\cancel{4}}{\cancel{12}} = \frac{50}{3} = 16.66V$

$V_6 = 50 \times \frac{\cancel{6}}{\cancel{12}} = 25V$

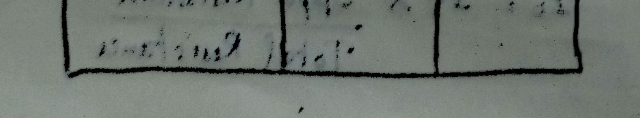
q) (1)



(2)



(3)



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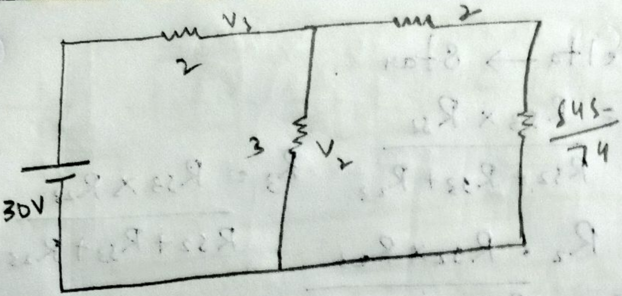

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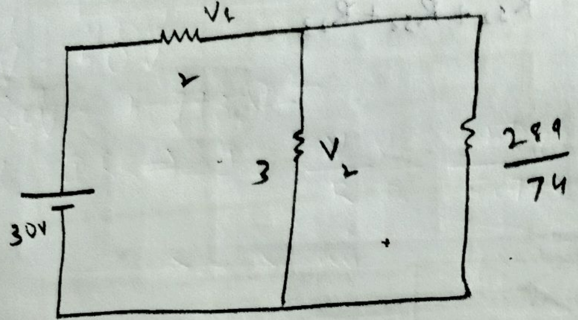
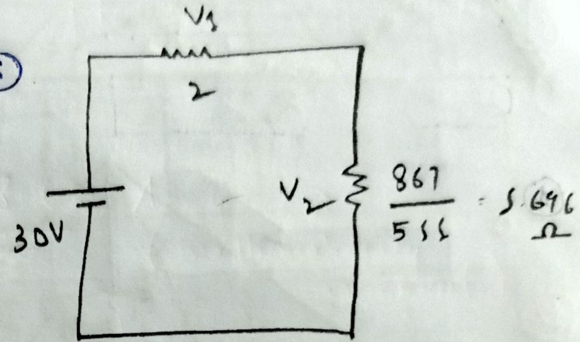


(6)

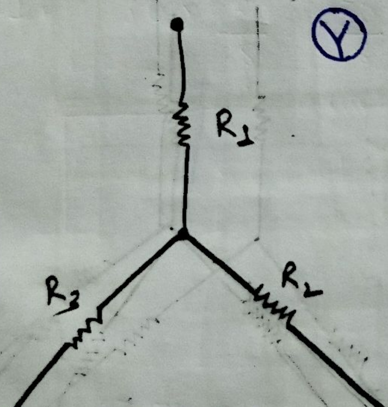


$$V_1 = 30 \times \frac{2}{3.696} = 16.233\ V$$

$$V_2 = 30 \times \frac{1.696}{3.696} = 13.766\ V$$

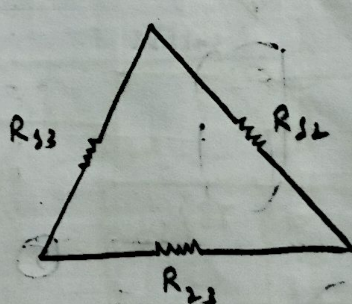
Star-Delta and Delta to Star Transformation :-

(Y)



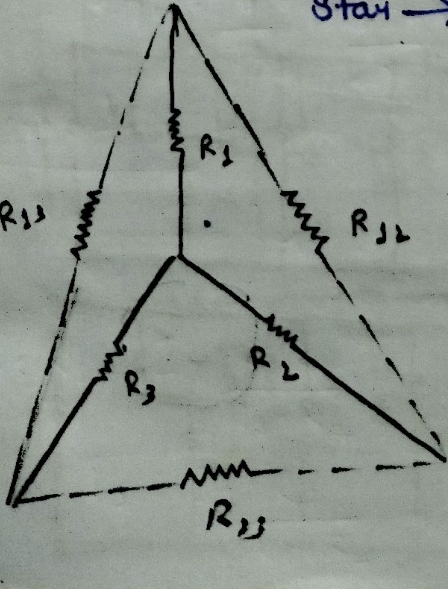
[Star]

(Δ)



[Delta]

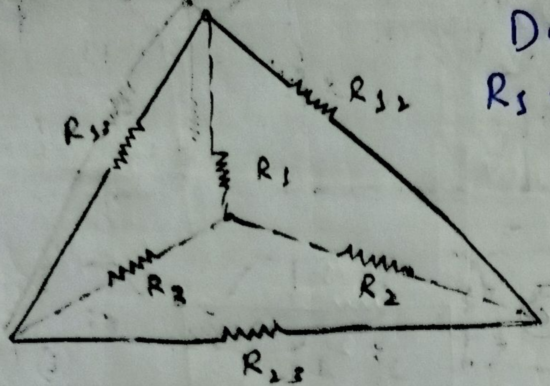
Star → Delta



$$R_{12} = R_1 + R_2 + \frac{R_1 R_2}{R_3}$$

$$R_{23} = R_2 + R_3 + \frac{R_2 R_3}{R_1}$$

$$R_{13} = R_1 + R_3 + \frac{R_1 R_3}{R_2}$$



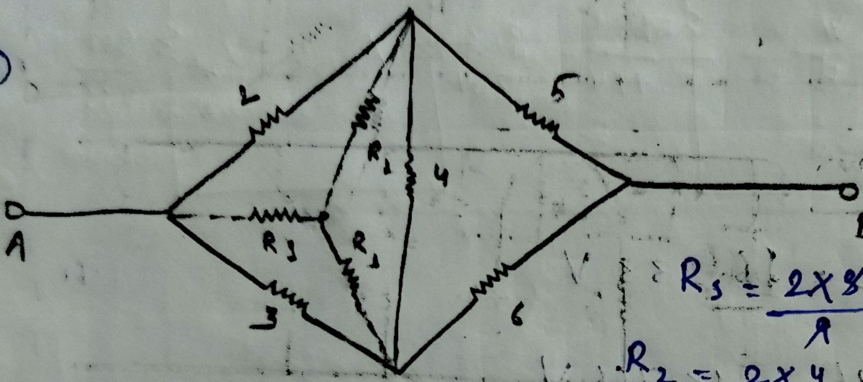
Delta → Star

$$R_1 = \frac{R_{13} \times R_{12}}{R_{12} + R_{13} + R_{23}}$$

$$R_3 = \frac{R_{13} \times R_{23}}{R_{12} + R_{13} + R_{23}}$$

$$R_2 = \frac{R_{12} \times R_{23}}{R_{12} + R_{13} + R_{23}}$$

(1)

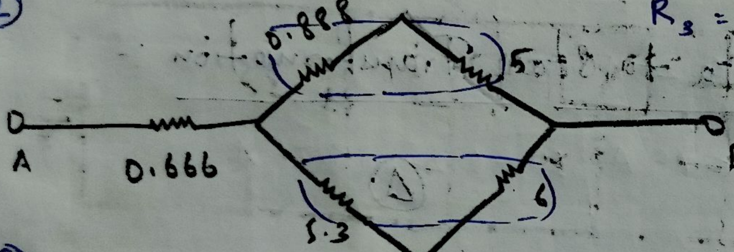


$$R_1 = \frac{2 \times 8}{9} = \frac{2}{3} = 0.666$$

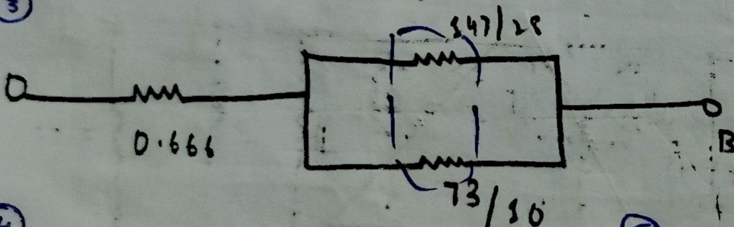
$$R_2 = \frac{2 \times 4}{9} = \frac{8}{9} = 0.888$$

$$R_3 = \frac{4 \times 8}{9} = \frac{4}{3} = 1.3$$

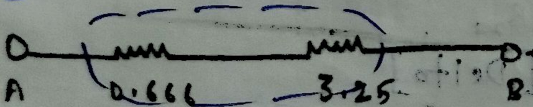
(2)



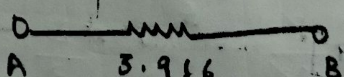
(3)



(4)

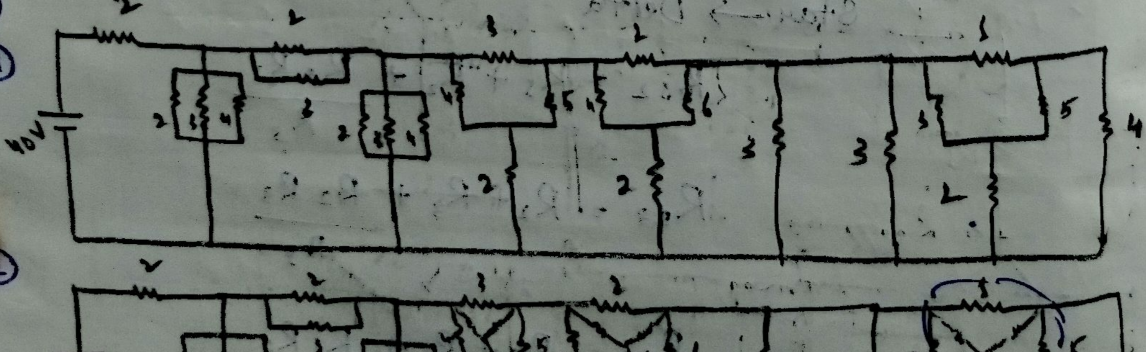


(5)

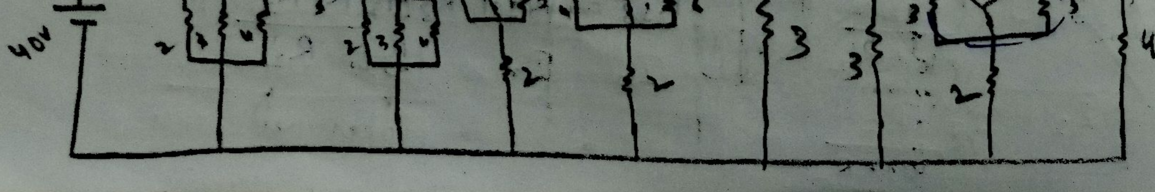


Q)

(1)



(2)



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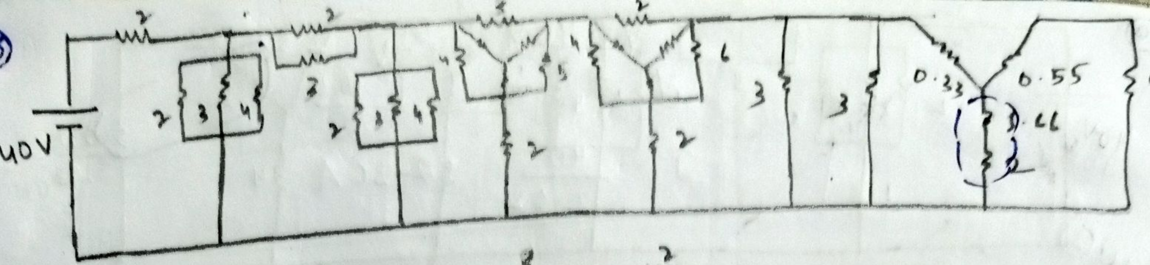
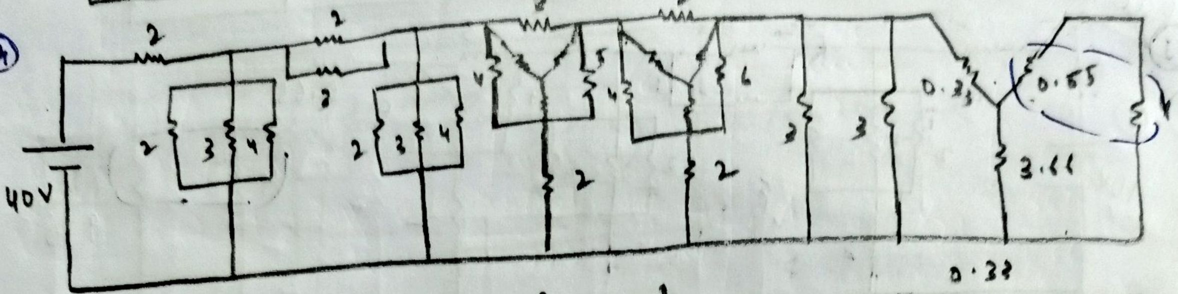
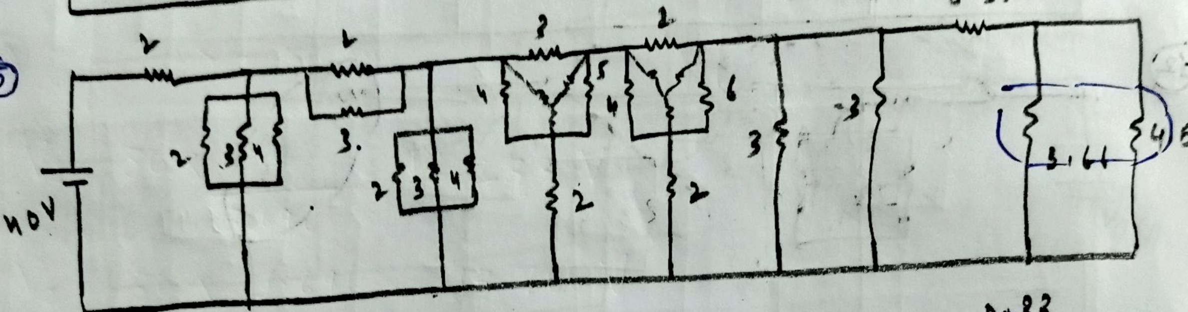

40V
0.33
0.55
0.66

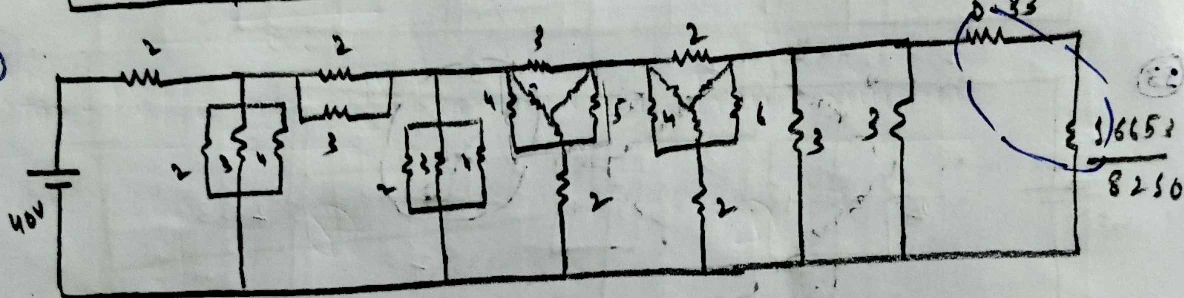
4


40V
0.33
0.55
3.66

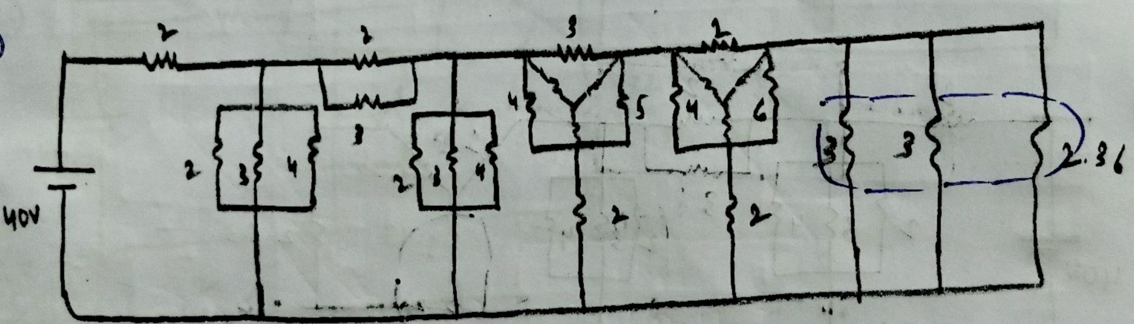
5


40V
0.33
3.66
55

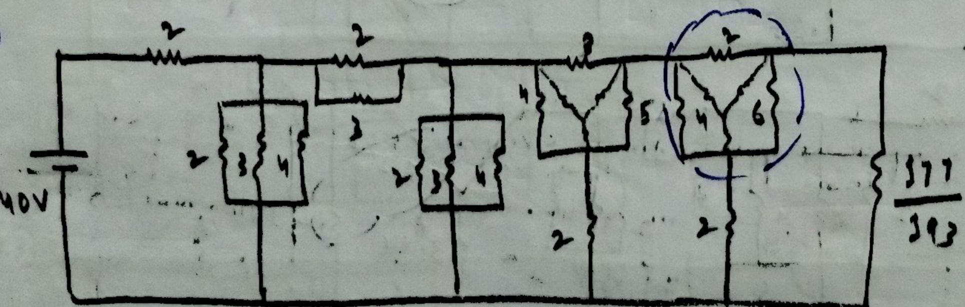
6


40V
0.33
16653
8250

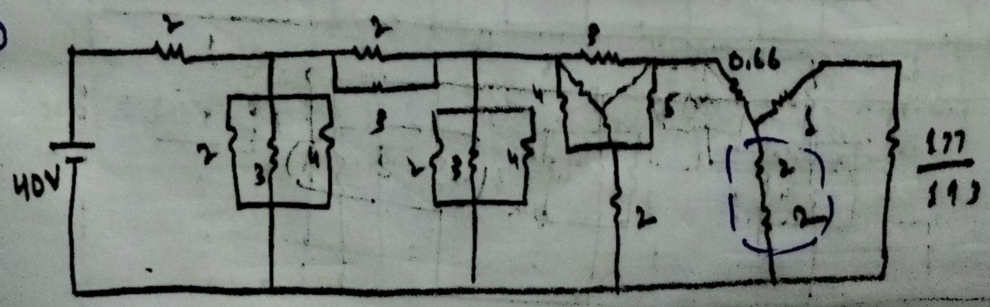
7


40V
2.36

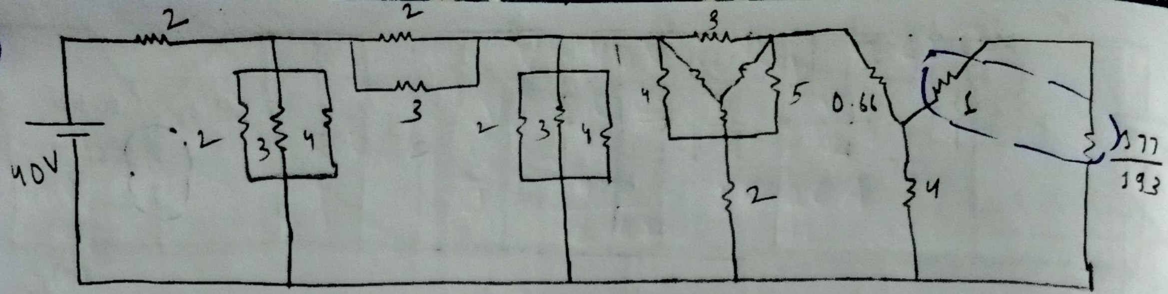
8


40V
377
393

9


40V
0.66
377
393

10



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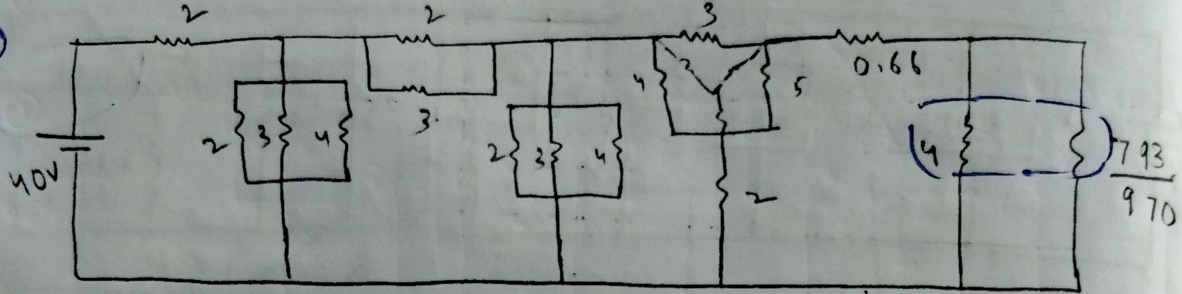

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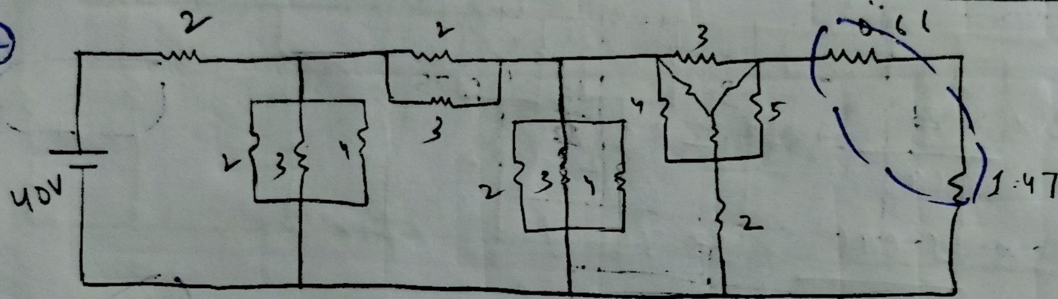

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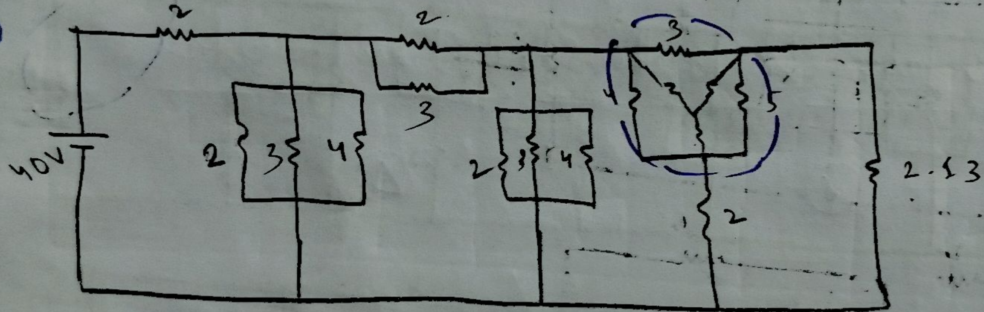

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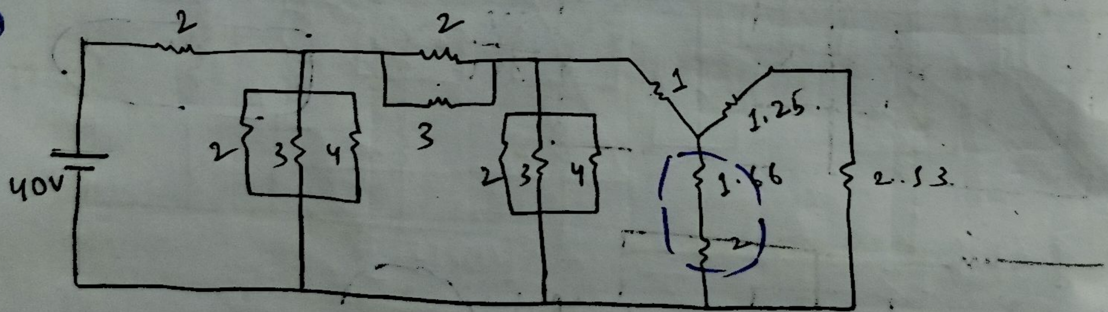

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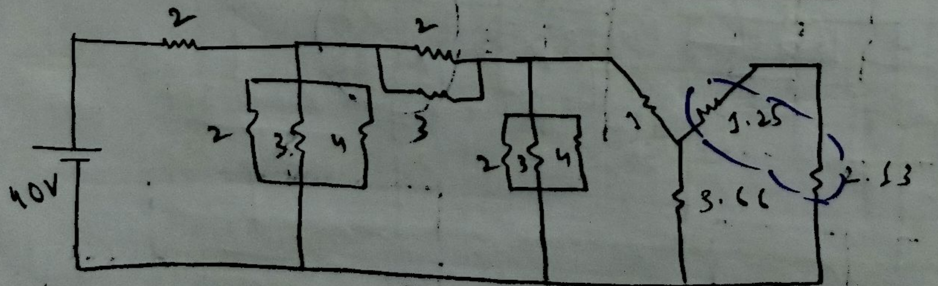

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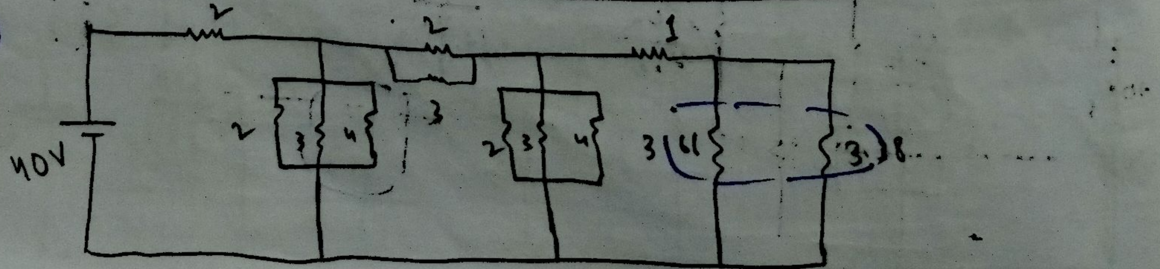

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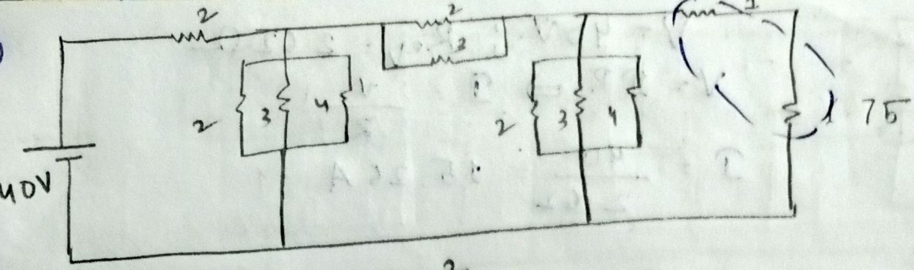

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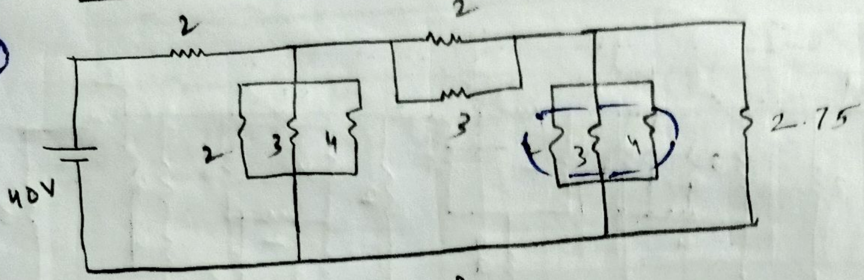

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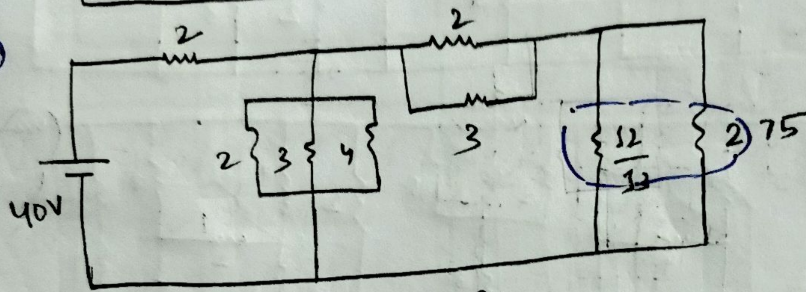

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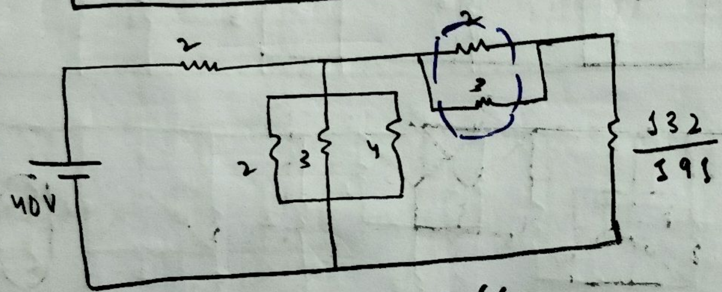

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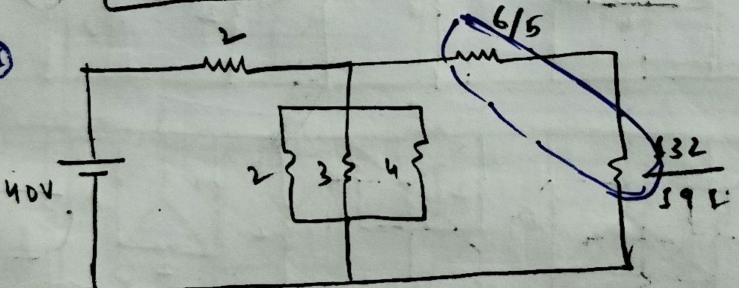

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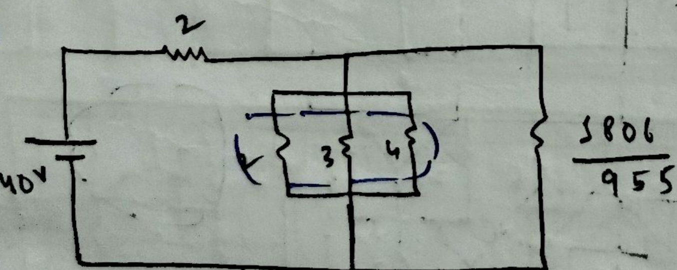

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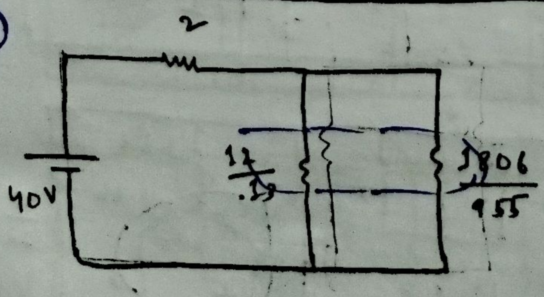

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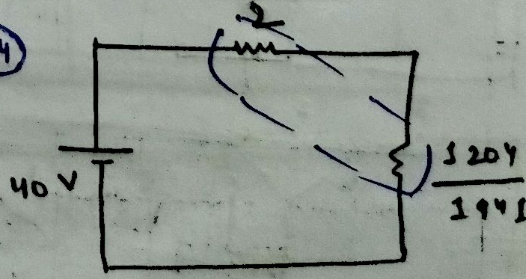
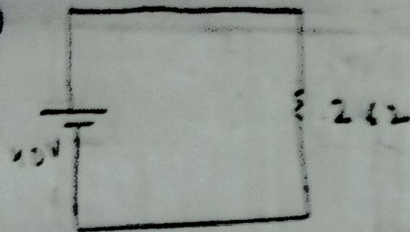


(25)



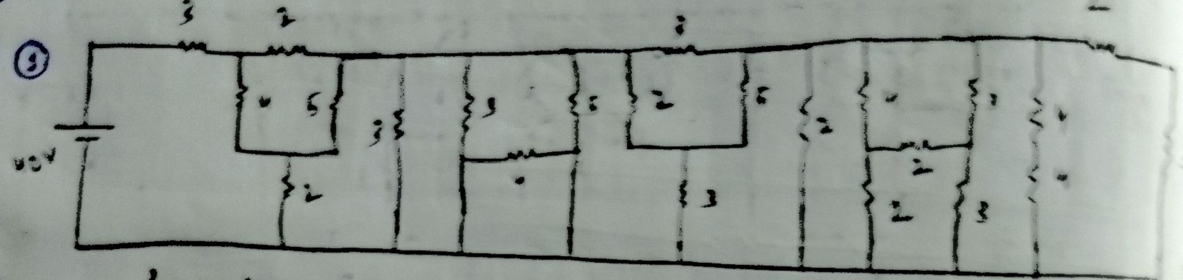
$V = 40V$; $R_{eq} = 2.62\Omega$

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

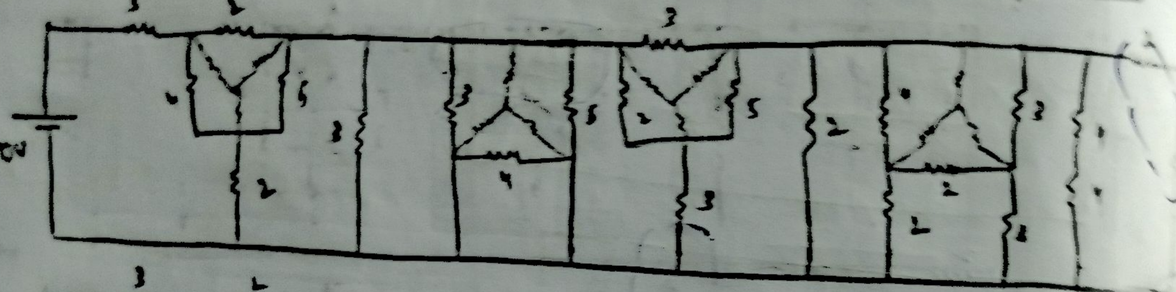
$I = \frac{40}{2.62} = 15.26\,A$

H.W (2)

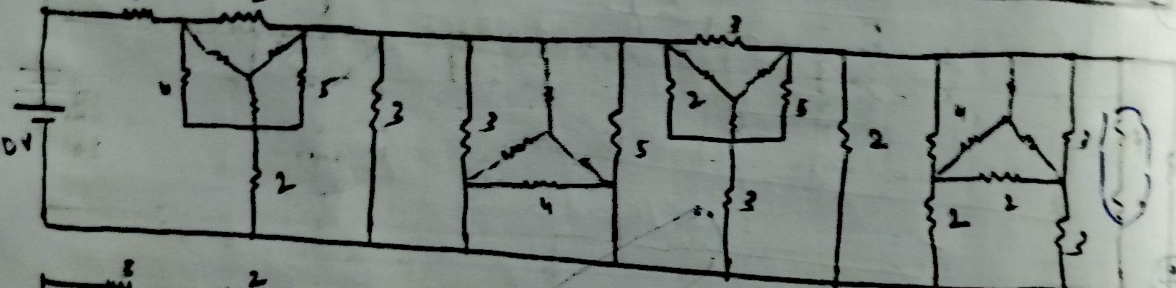
1) (1)



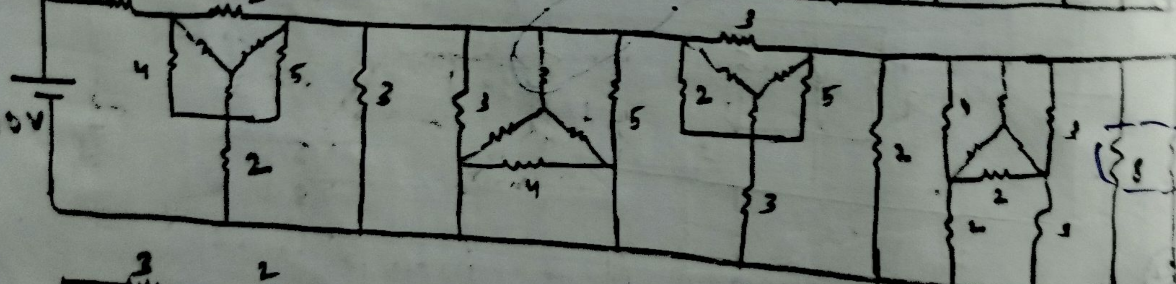
(2)



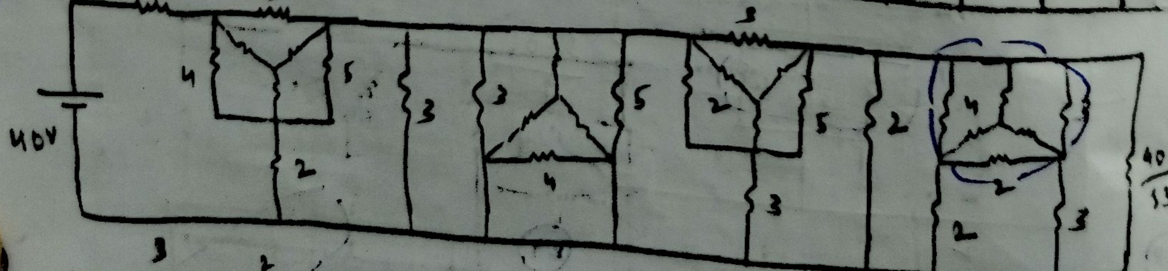
(3)

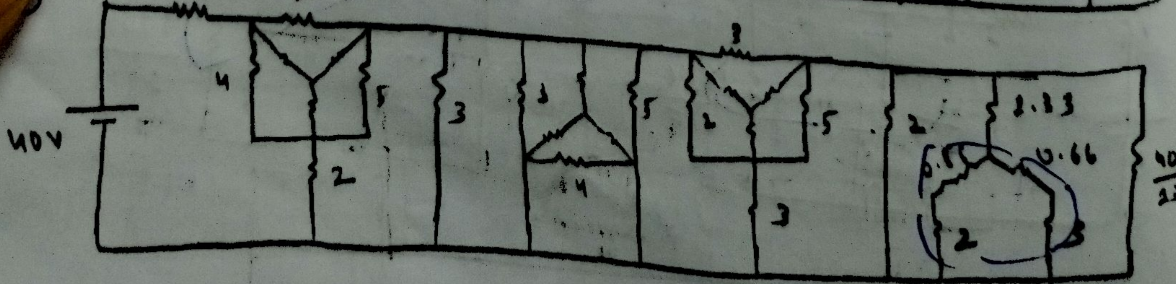


(4)



(5)





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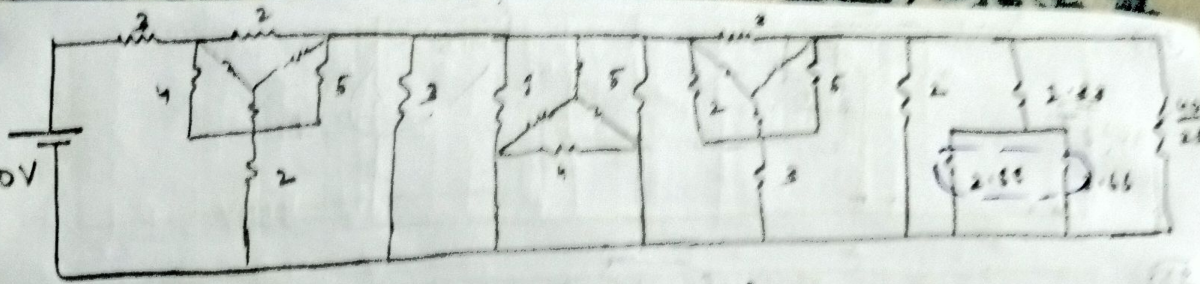
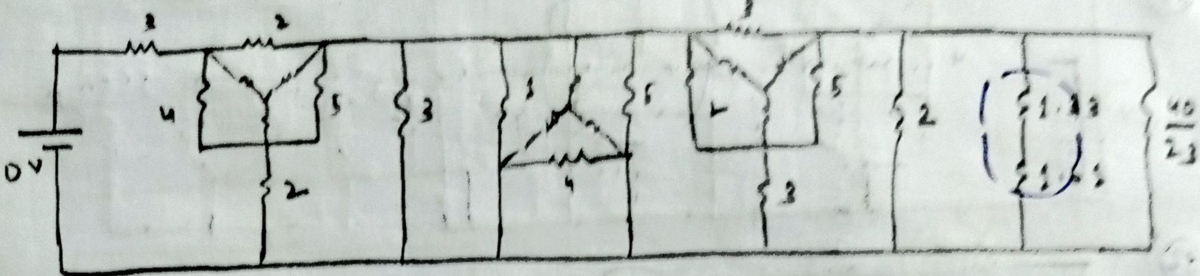
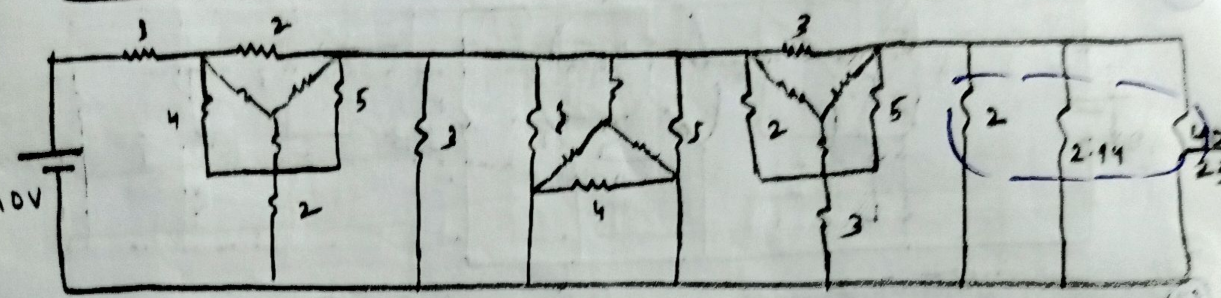


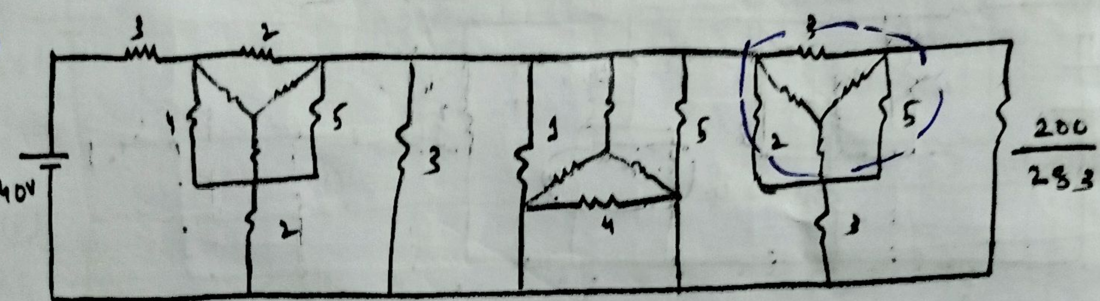
(8)



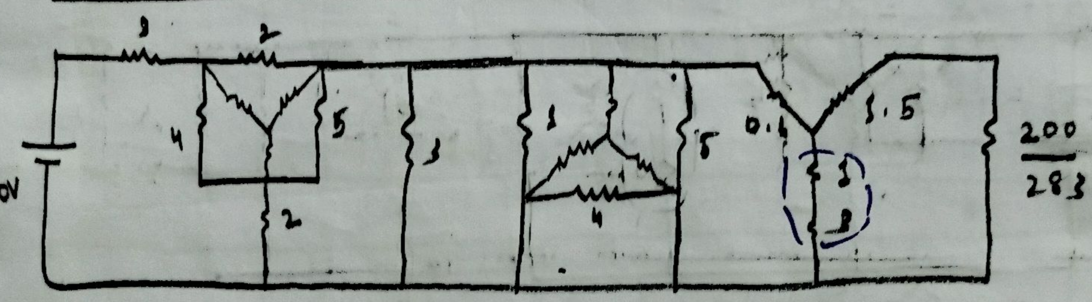
(9)



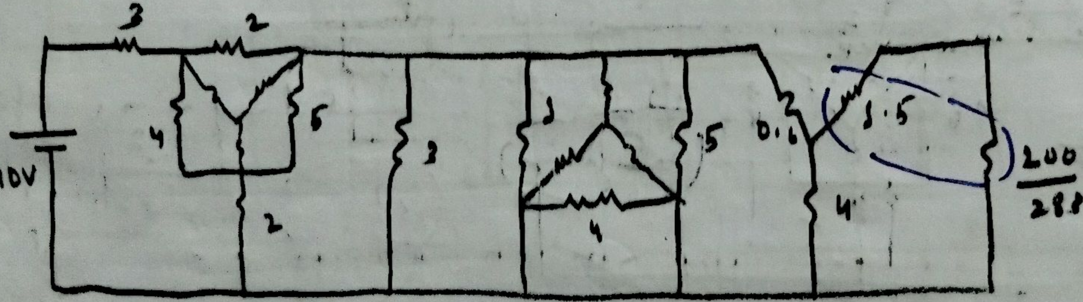
(10)



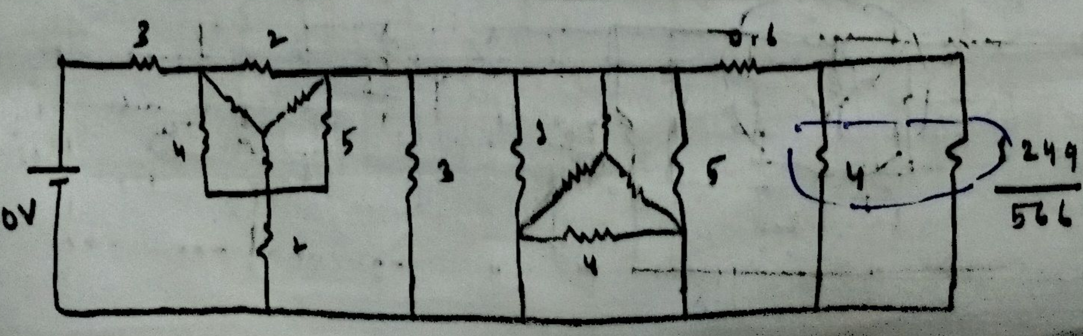
(11)



(12)



(13)



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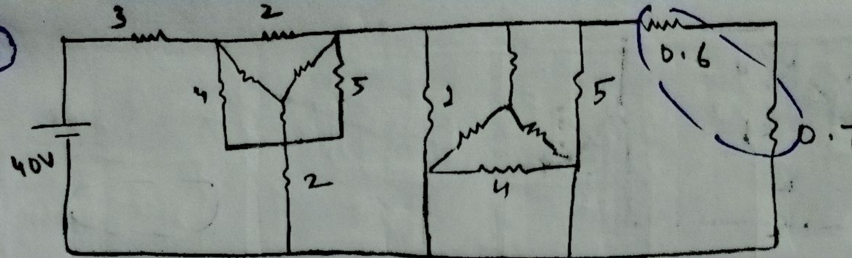

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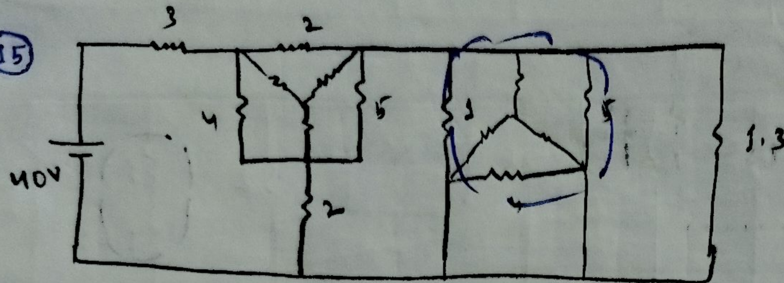

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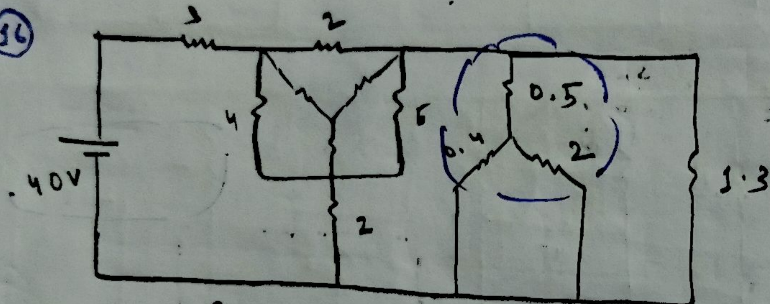

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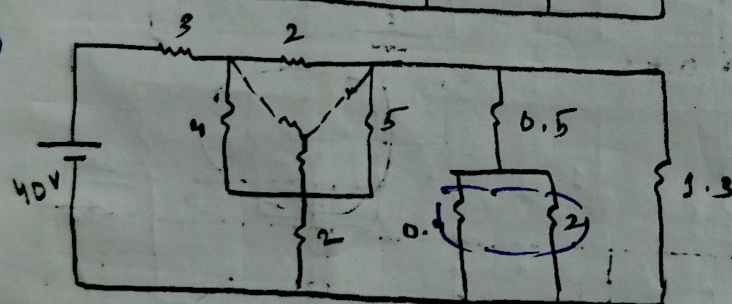

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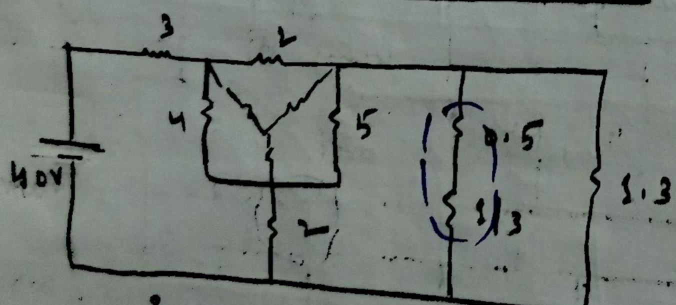

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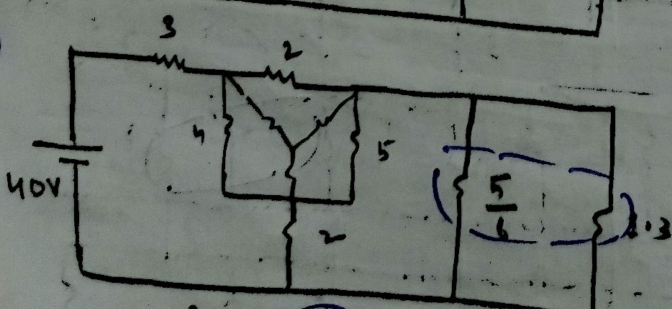
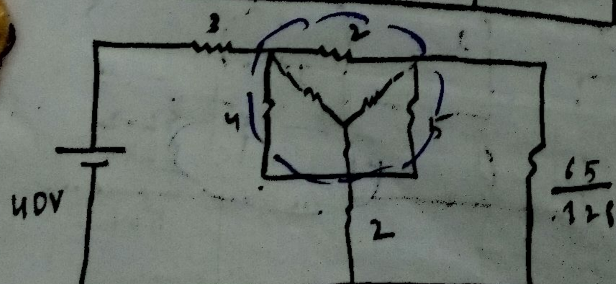
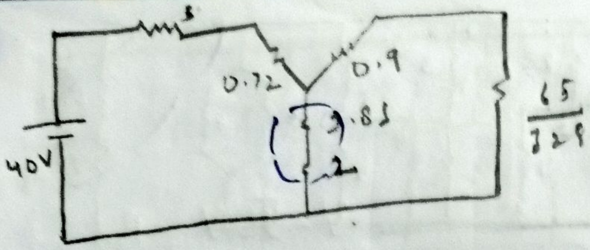




(21)



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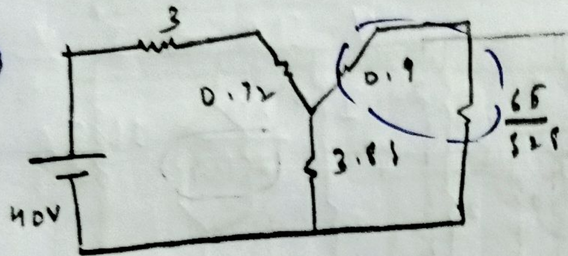
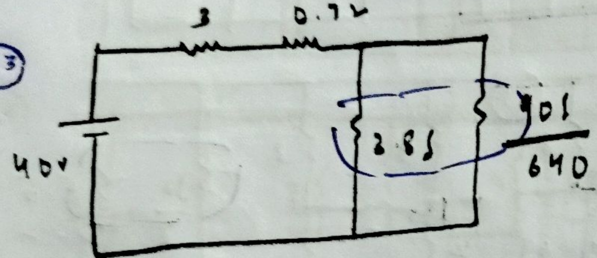


(23)

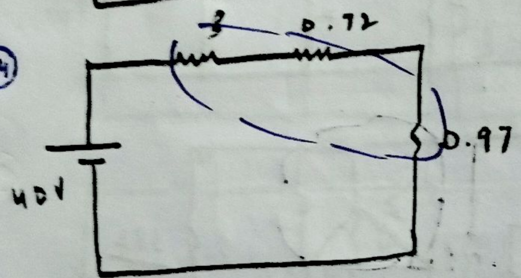


$V = 40V$; $R_{eq} = 4.69\Omega$

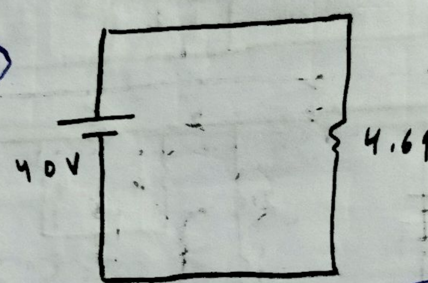
$V = IR \Rightarrow I = \frac{V}{R}$

$I = \frac{40}{4.69} = 8.52A$

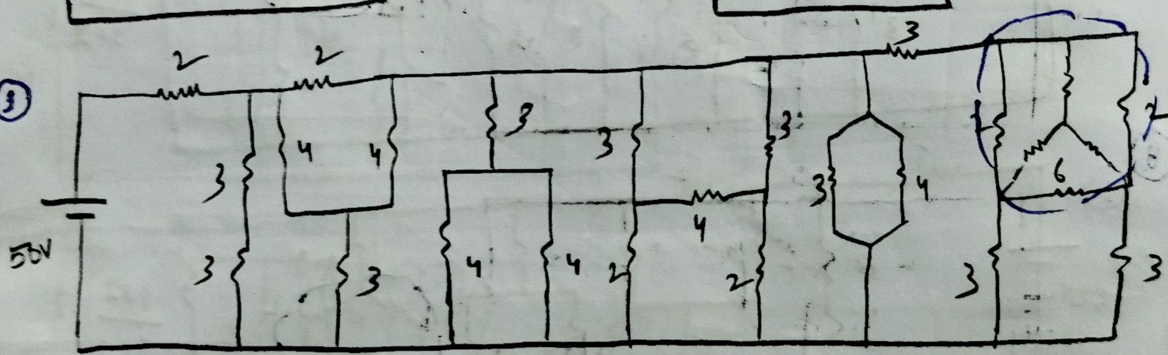
(24)



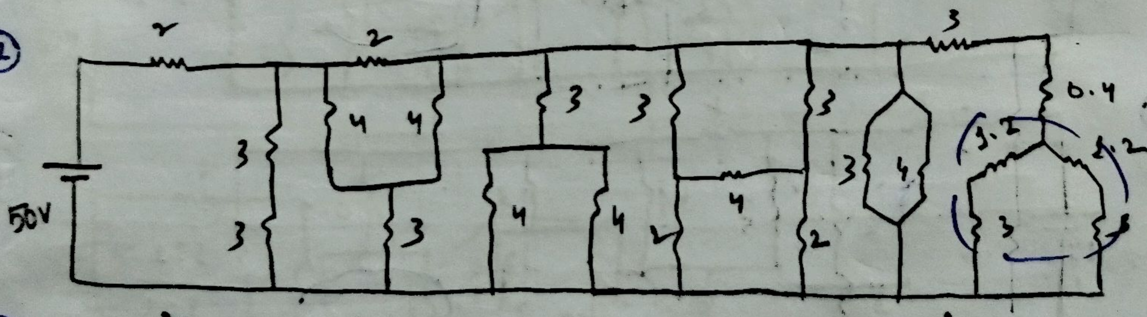
(25)



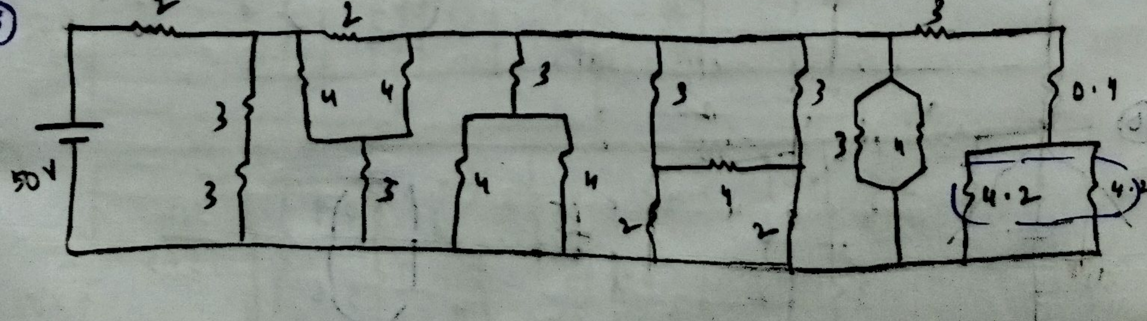
a) (1)

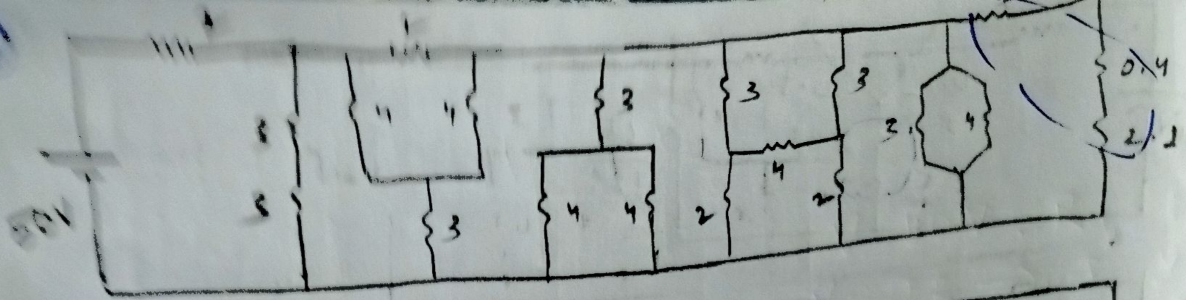


(2)

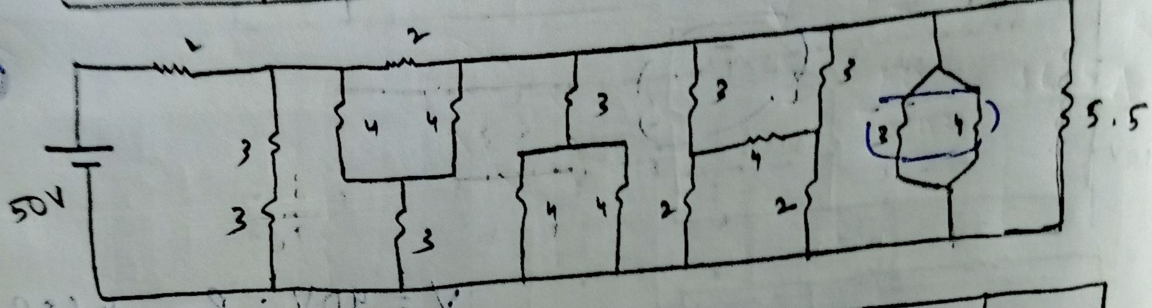


(3)

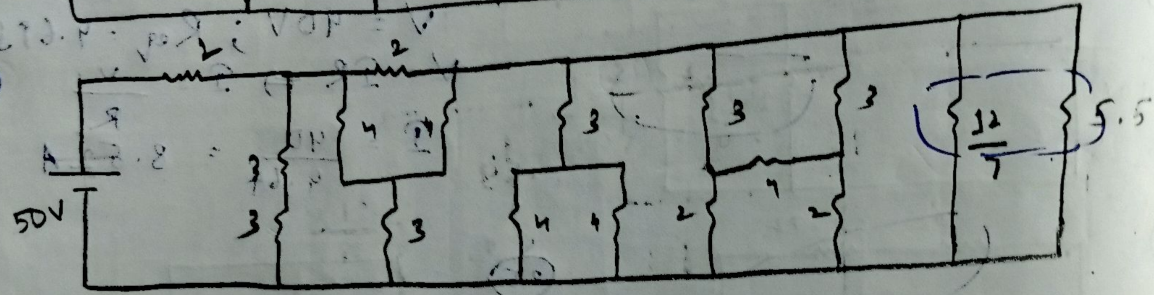



50V
3
3
4 4
3
3
4 4
3
2
3
4
2
3
2
4
0.4
2.1

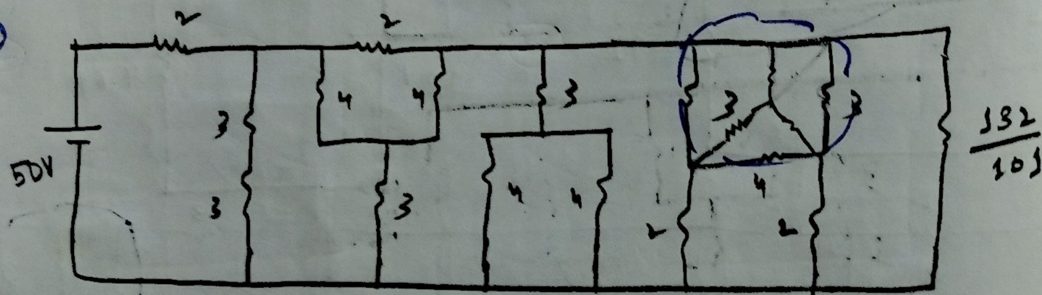
5


2
2
50V
3
3
4 4
3
3
4 4
2
3
4
2
3
3
4
5.5

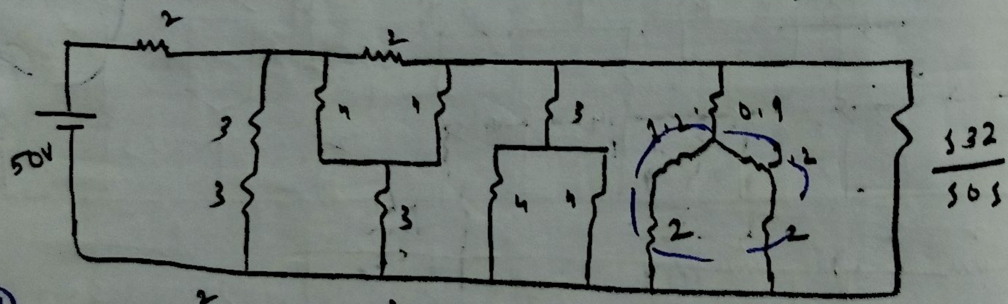
6


2
2
50V
3
3
4 4
3
3
4 4
2
3
4
2
3
12/7
5.5

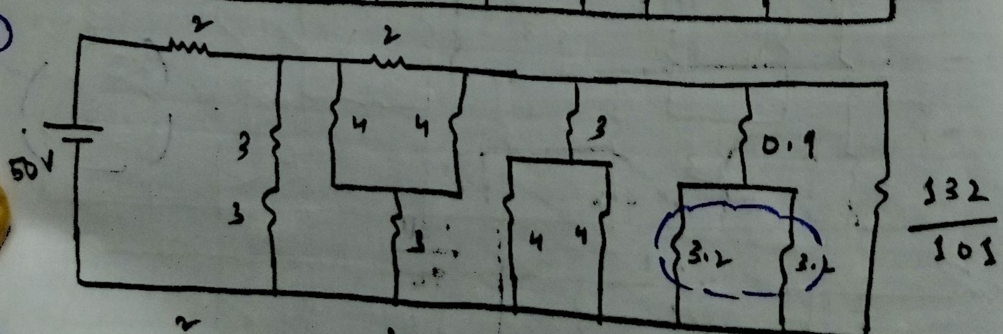
7


2
2
50V
3
3
4 4
3
3
4 4
3
3
4
2
2
132/101

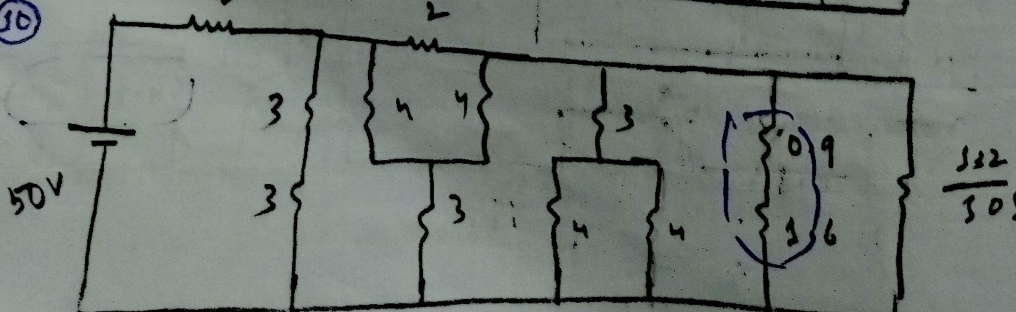
8


2
2
50V
3
3
4 4
3
3
4 4
0.9
2
2
132/101

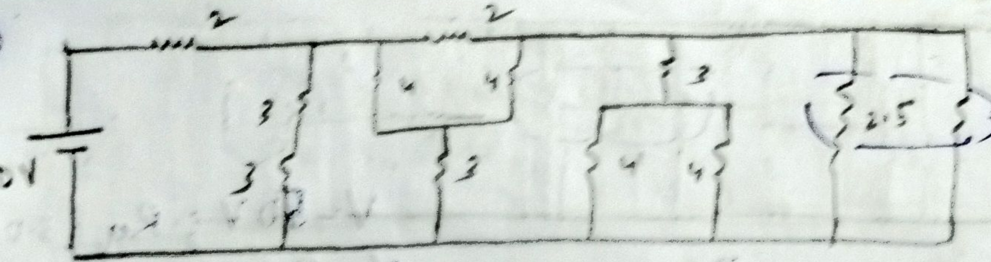
9


2
2
50V
3
3
4 4
3
3
4 4
0.9
3.2
3.2
132/101

10

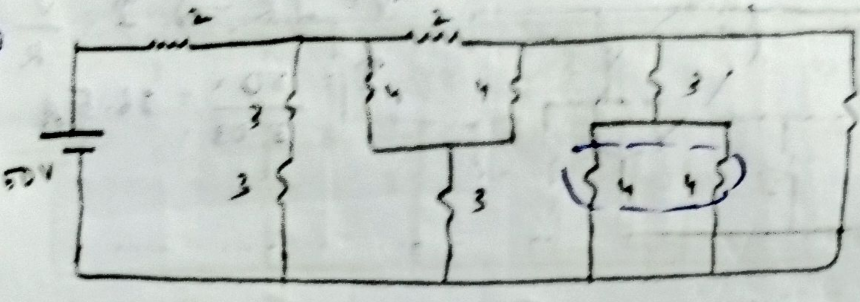

2
2
50V
3
3
4 4
3
3
4 4
0.9
1.6
132/101

(11)



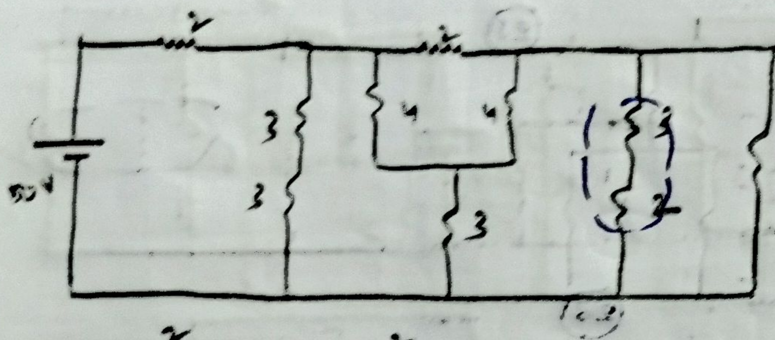
$\frac{132}{301}$

(12)



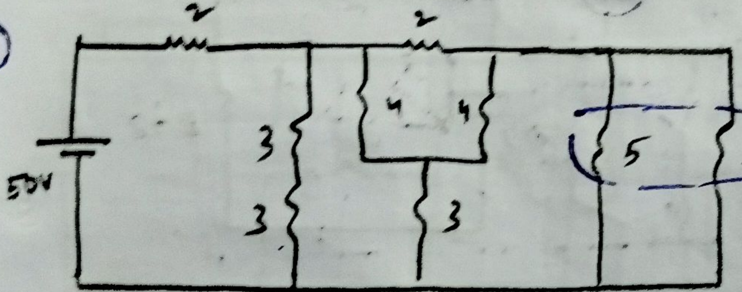
$\frac{660}{769}$

(13)



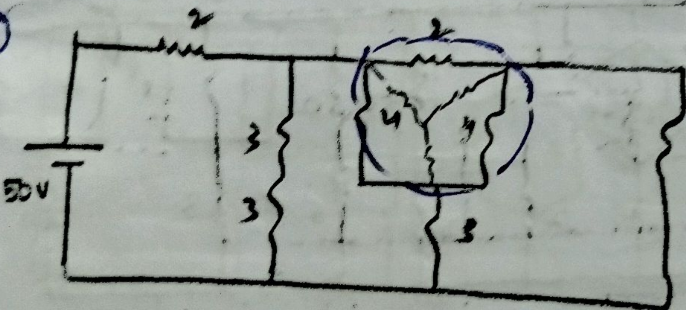
$\frac{660}{769}$

(14)



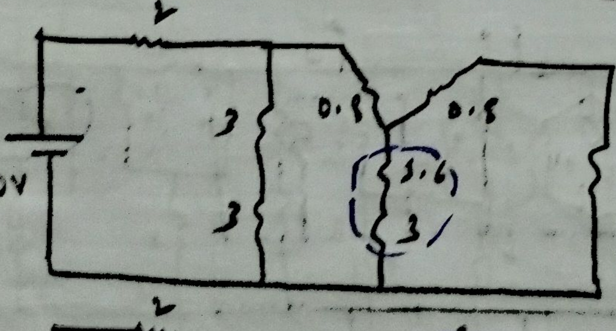
$\frac{660}{769}$

(15)



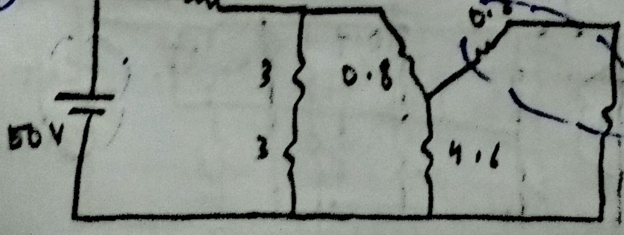
$\frac{660}{905}$

(16)



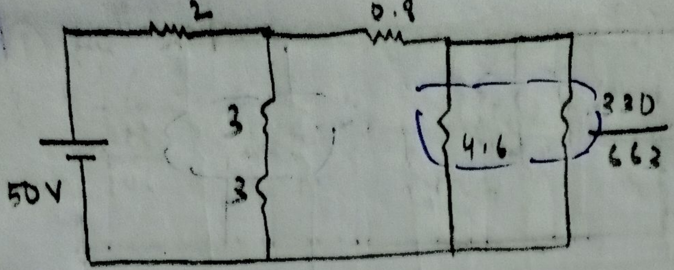
$\frac{660}{901}$

(17)



$\frac{660}{905}$

18

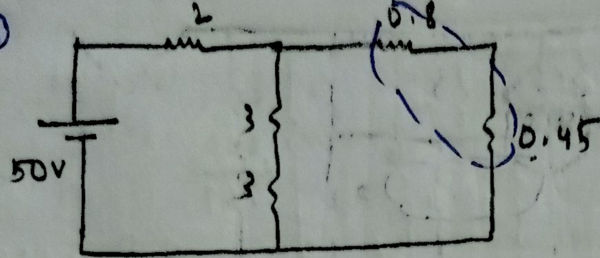


$V = 50\,V$; $R_{eq} = 3.03\,\Omega$

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

$I = \frac{50}{3.03} = 16.5\,A$

19



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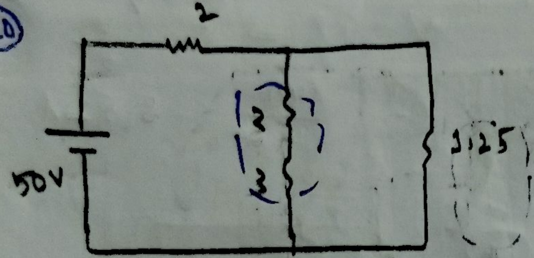

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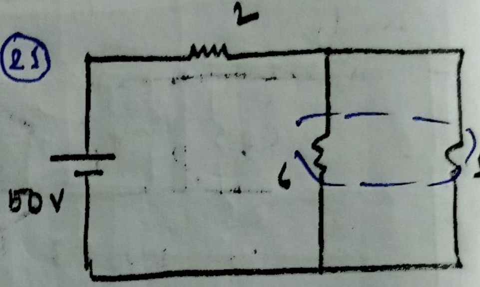

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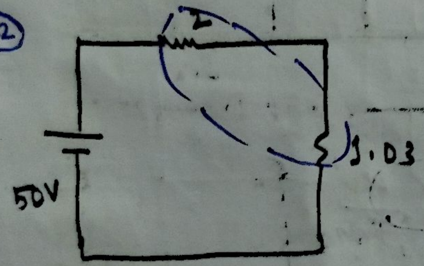
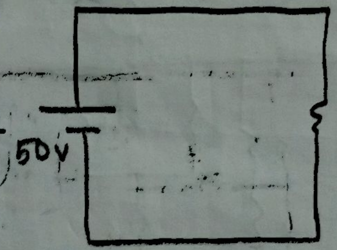
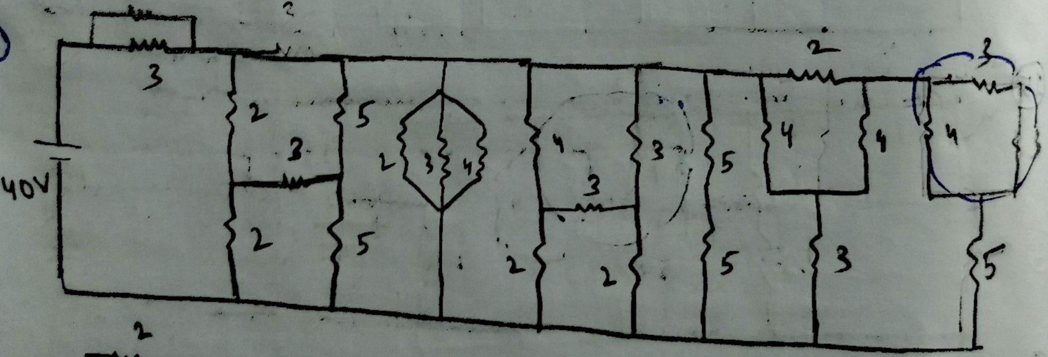


23

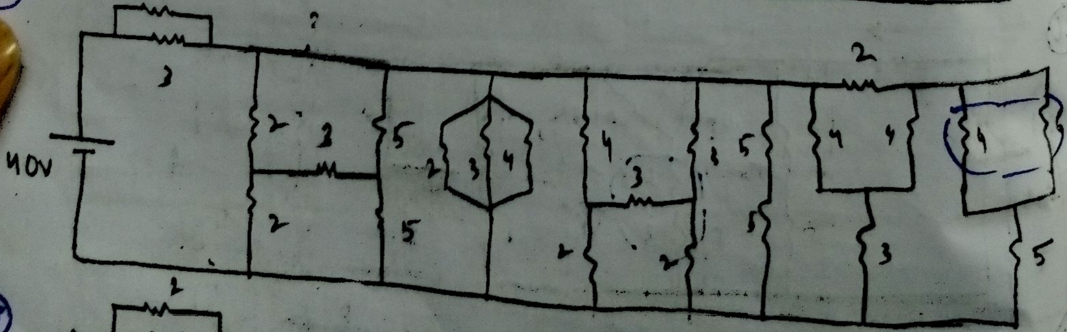


q)

1



2



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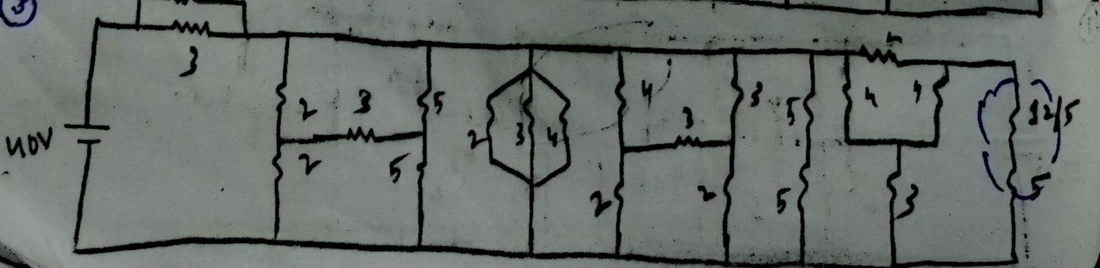
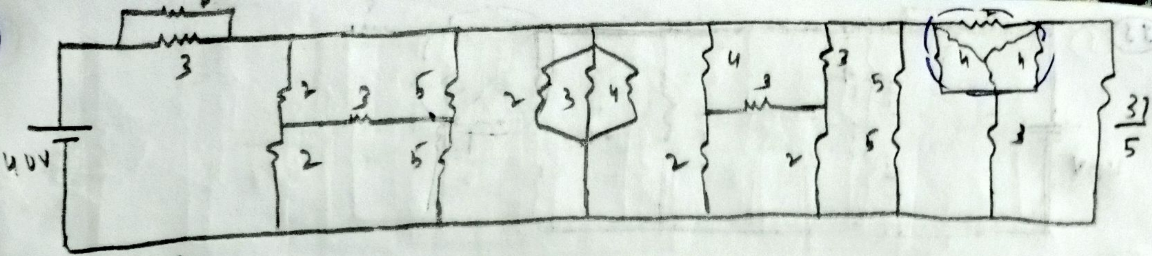
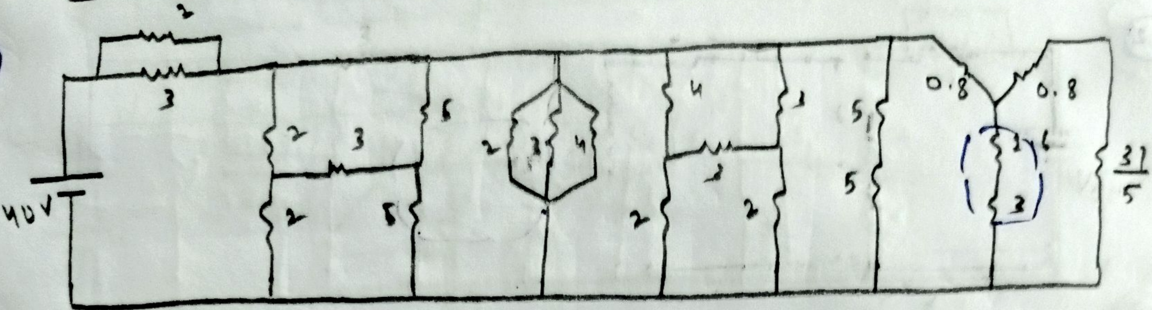


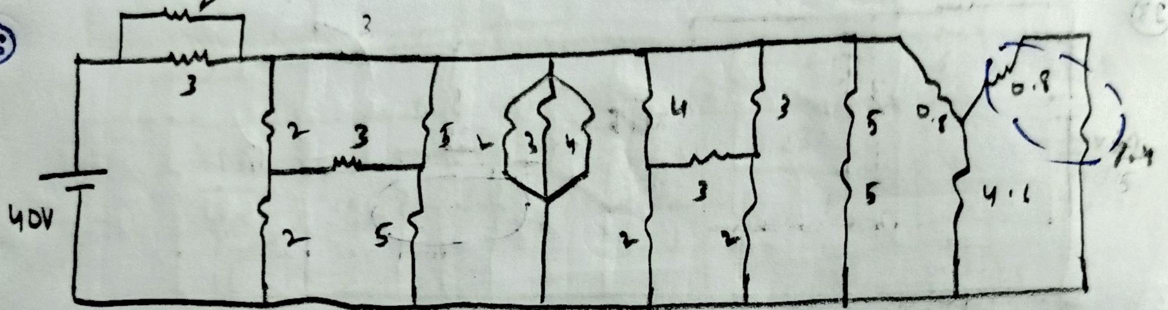
④


40V
3
2
3
5
2
5
2
3
4
4
3
2
2
3
5
5
4
4
3
31/5

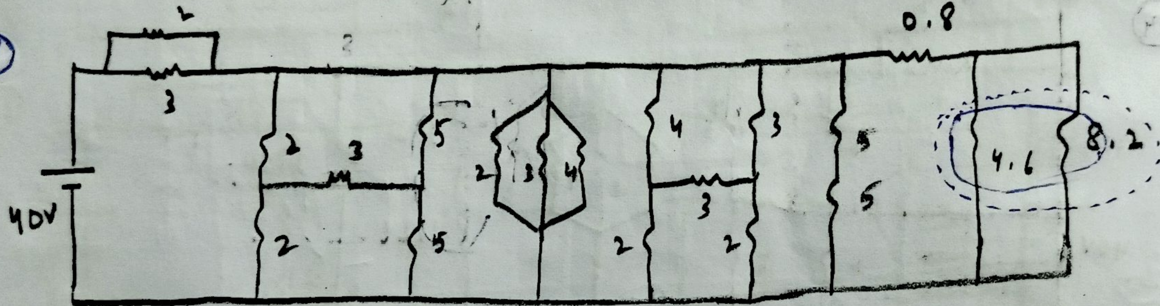
⑤


2
3
40V
2
3
2
5
5
2
3
4
4
3
2
2
5
5
0.8
0.8
3
3
31/5

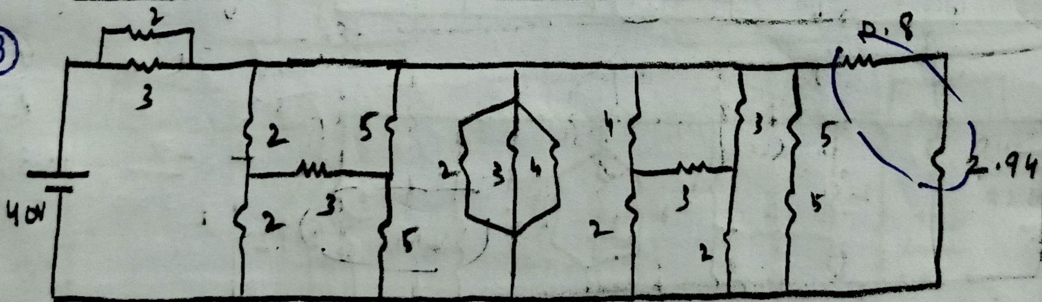
⑥


2
3
40V
2
3
2
5
5
2
3
4
4
3
3
2
2
5
5
0.8
0.8
4.6

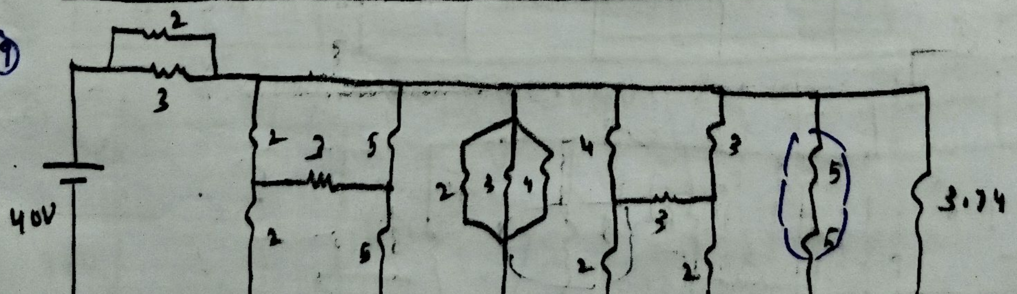
⑦


2
3
40V
2
3
2
5
5
2
3
4
4
3
3
2
2
5
5
0.8
4.6
8.2

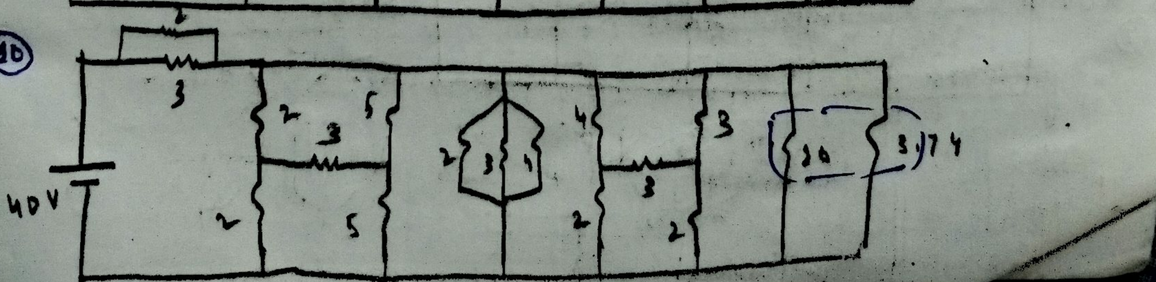
⑧


2
3
40V
2
5
2
3
5
2
3
4
4
2
3
3
2
5
5
0.8
2.94

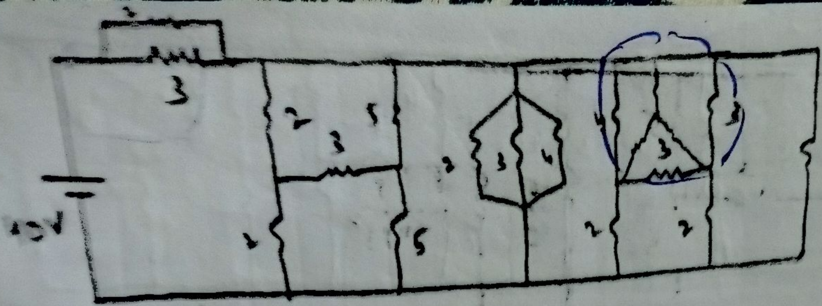
⑨


2
3
40V
2
3
5
2
5
2
3
4
4
2
3
3
2
5
5
3.74

⑩

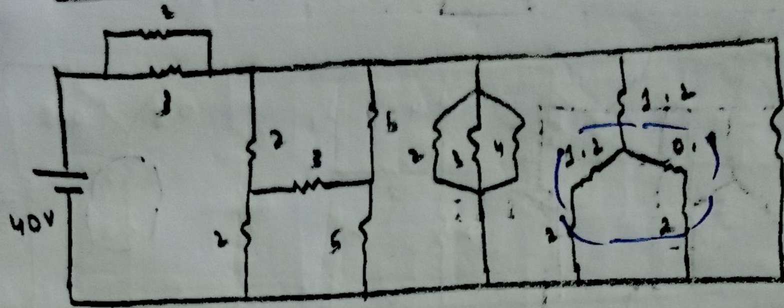

2
3
40V
2
3
5
2
5
2
3
4
4
2
3
3
2
10
3.74

11



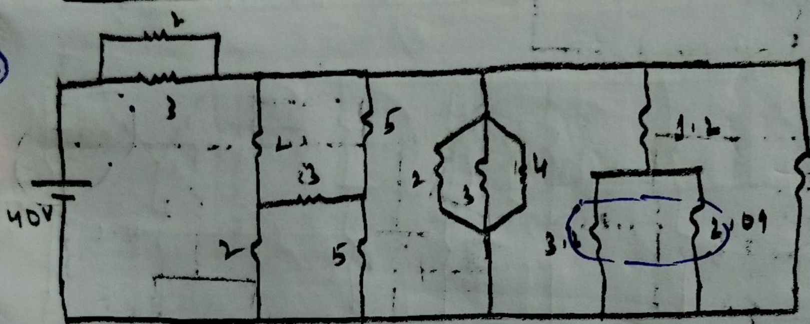
$\frac{1810}{687}$

12



$\frac{1810}{687}$

13



$\frac{1810}{681}$

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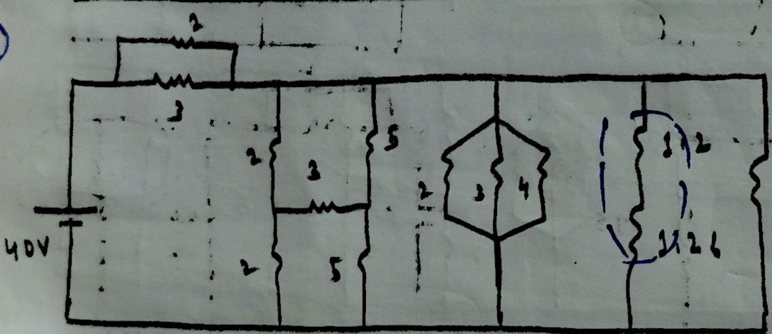
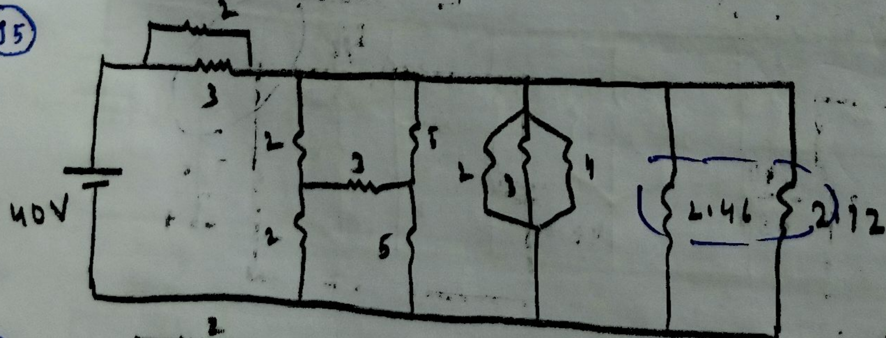
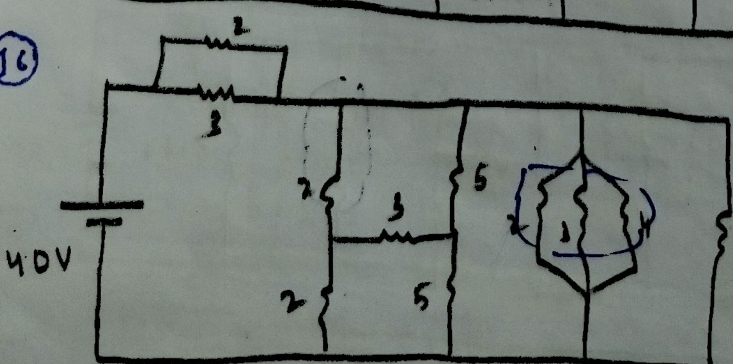


$\frac{1810}{687}$

15

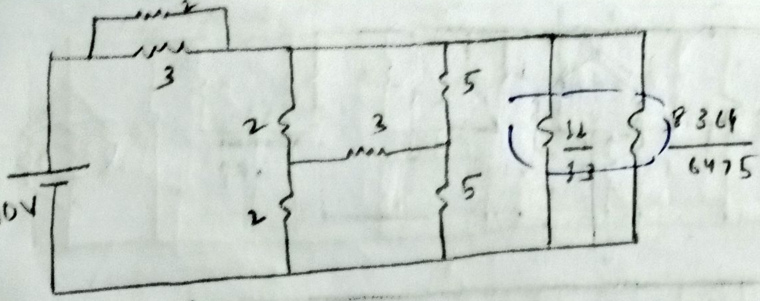


16

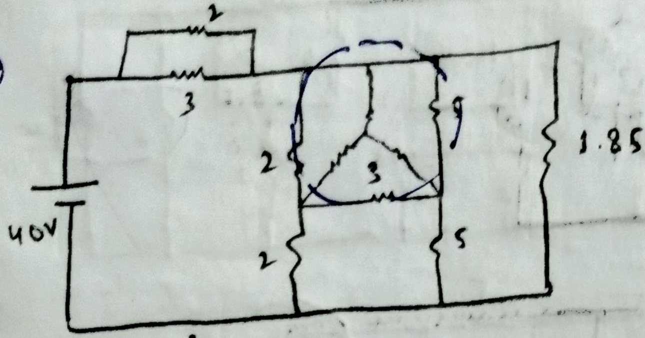


$\frac{8864}{647.5}$

17



18



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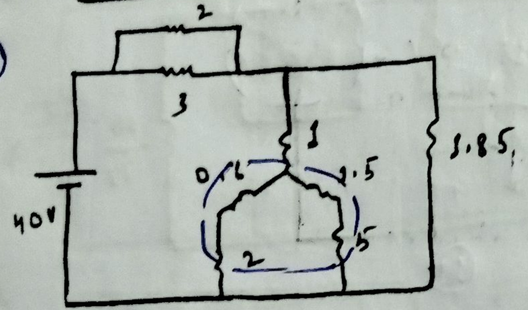

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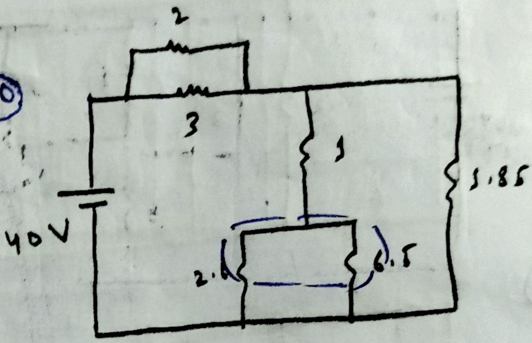

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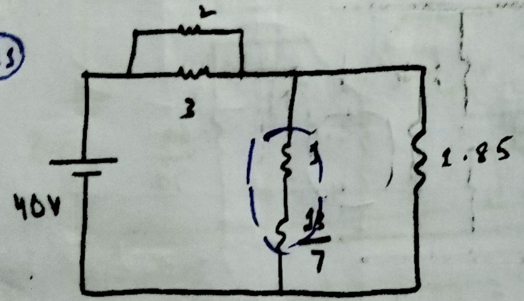

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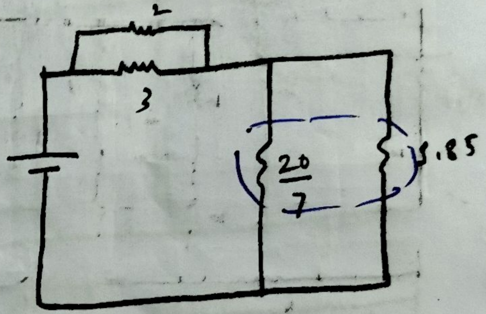

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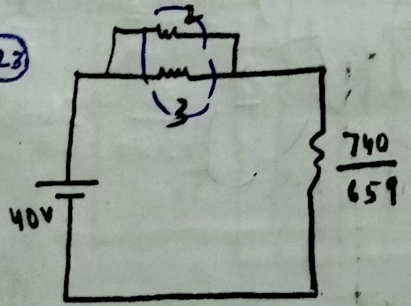

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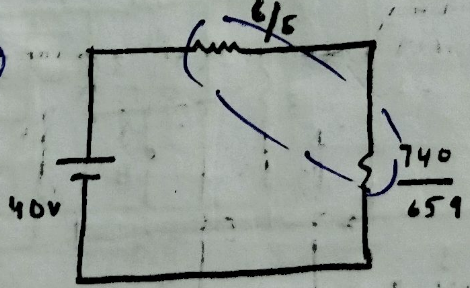

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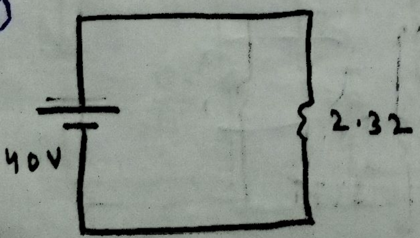
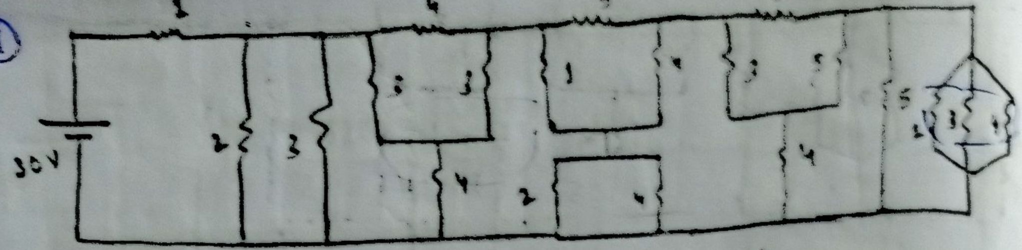


$V = 40V$; $R_{eq} = 2.32\,\Omega$

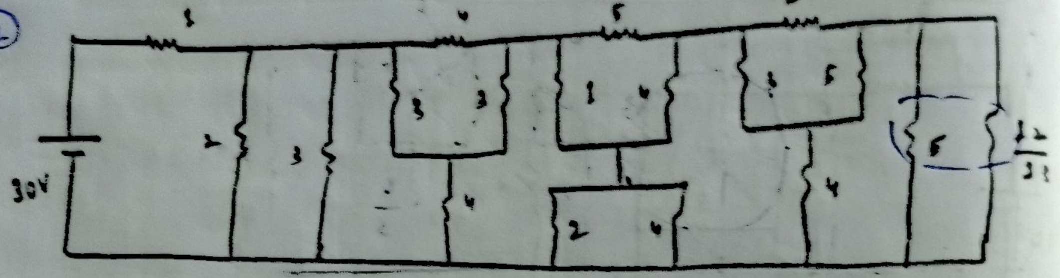
$V = IR \Rightarrow I = \frac{V}{R}$

$I = \frac{40}{2.32} = 17.24\,A$

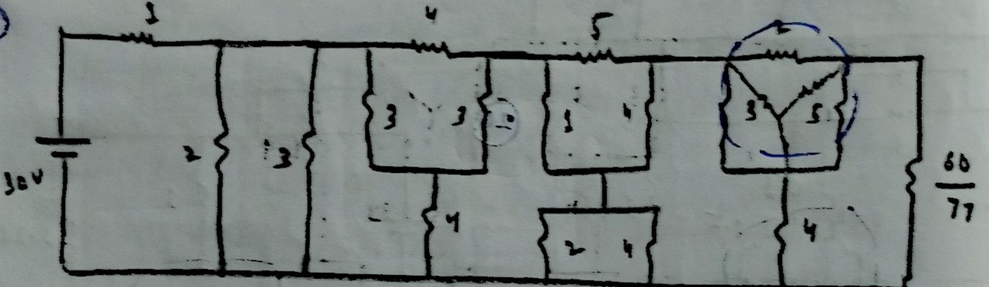
9) 1


30V

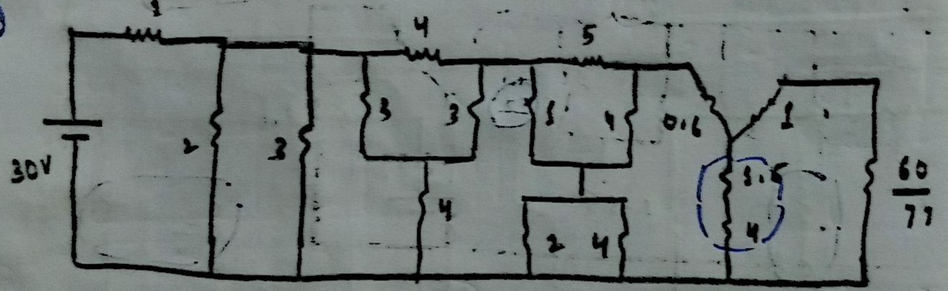
2


30V
12/33

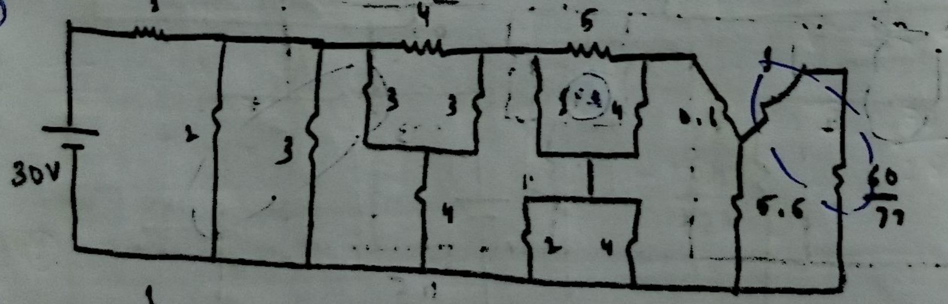
3


30V
60/77

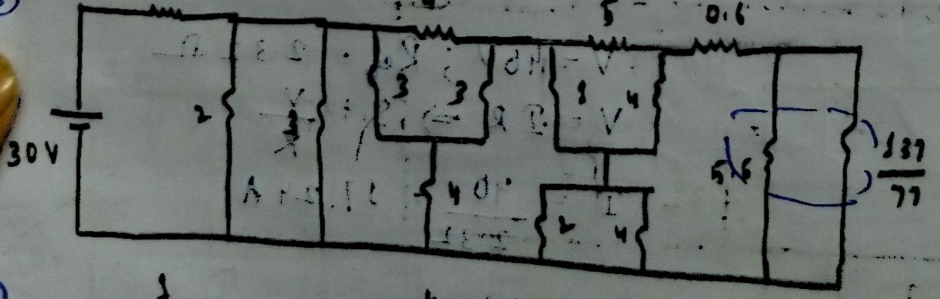
4


30V
0.6
60/77

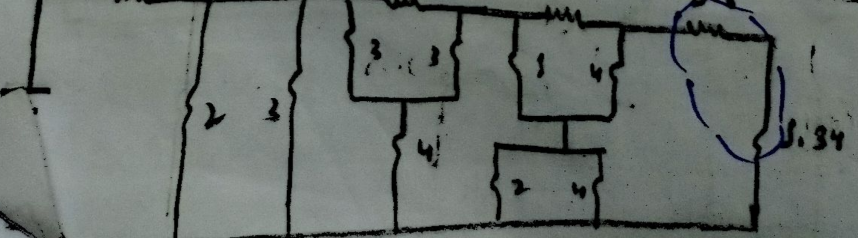
5


30V
0.6
5.6
60/77

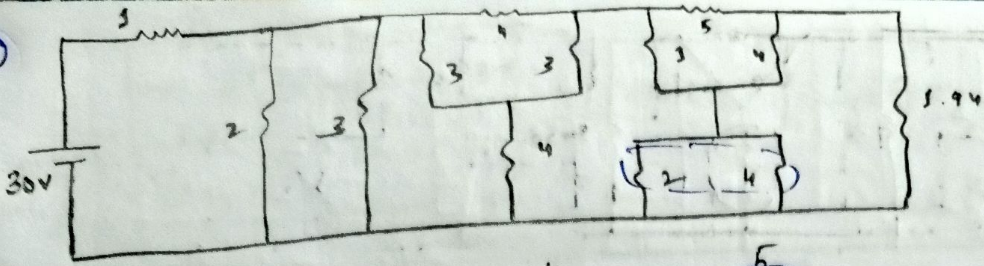
6


30V
0.6
5.6
137/77

7


0.6

(8)



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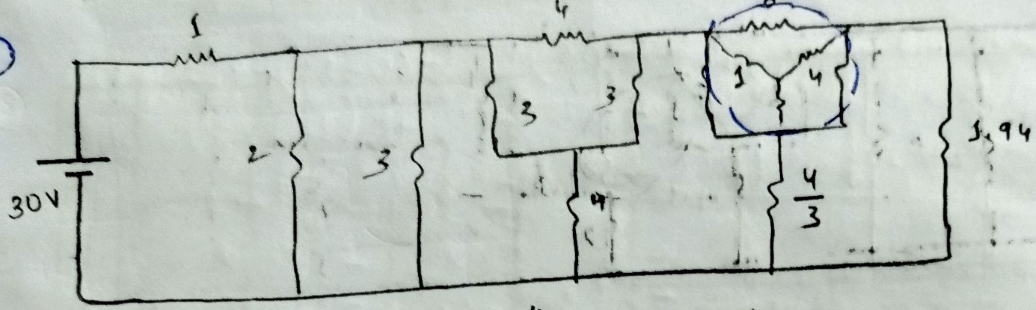

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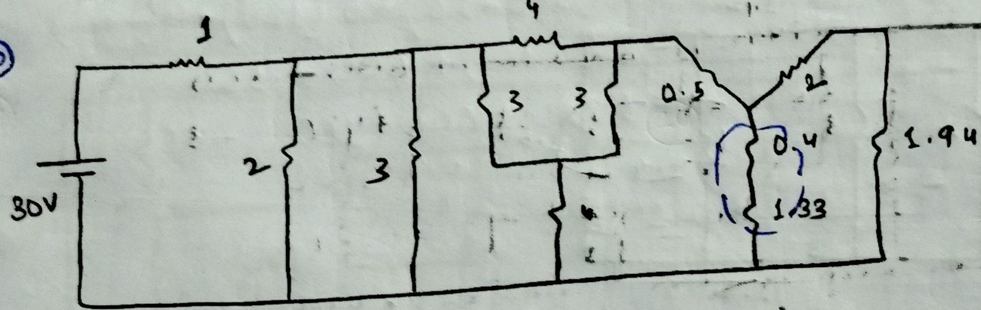

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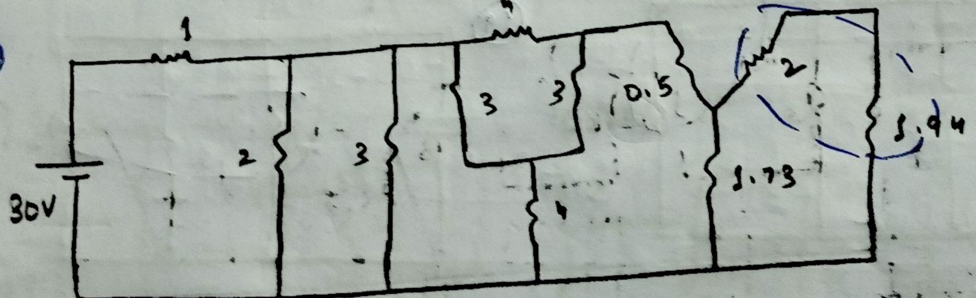

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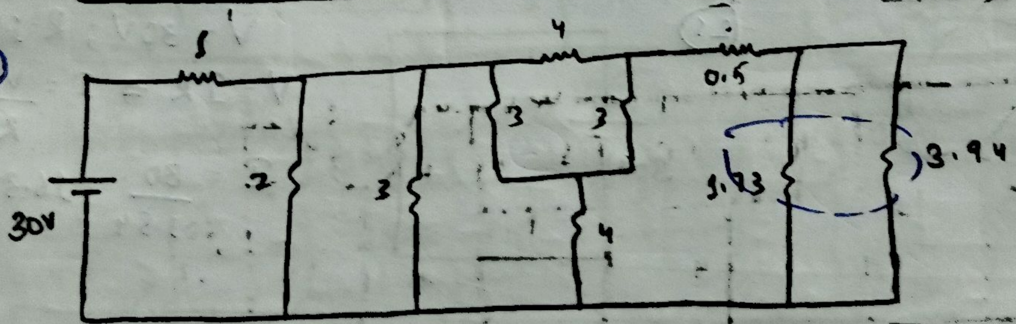

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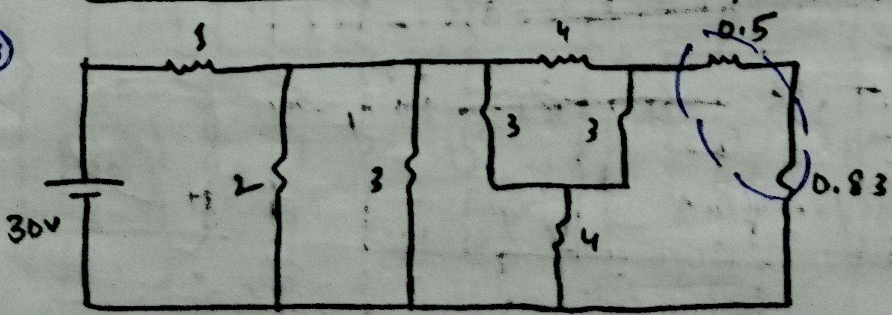

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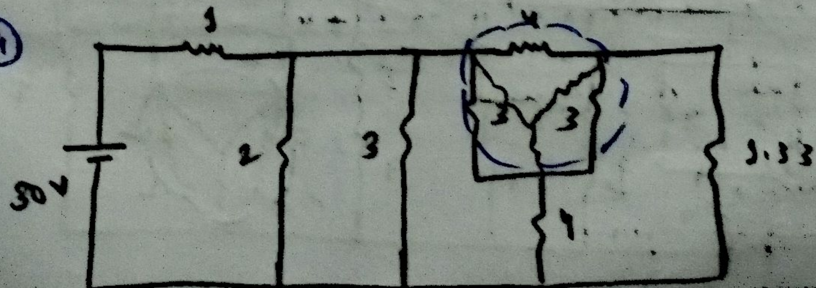

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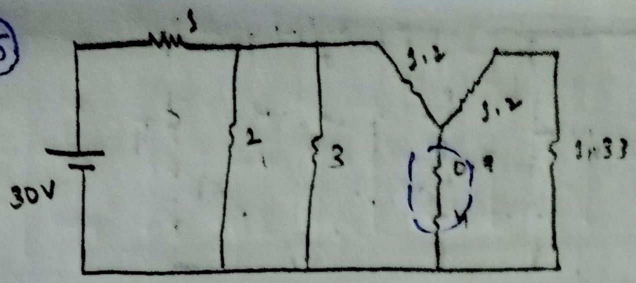

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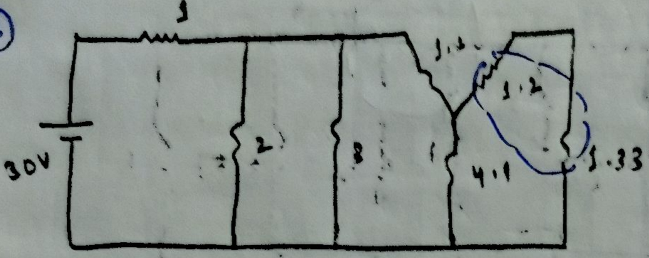

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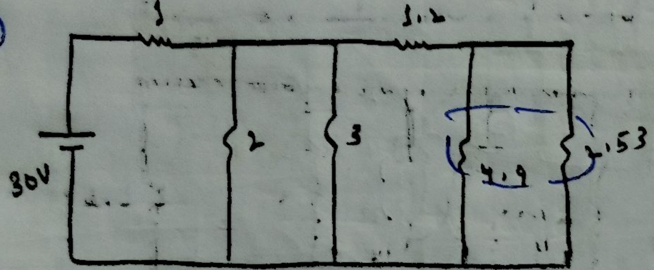

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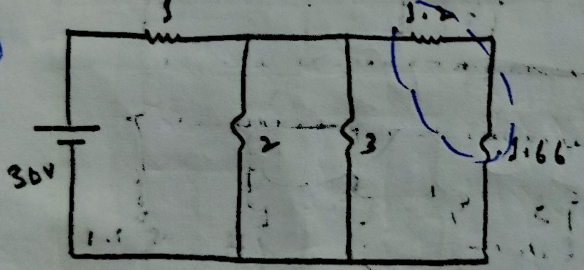

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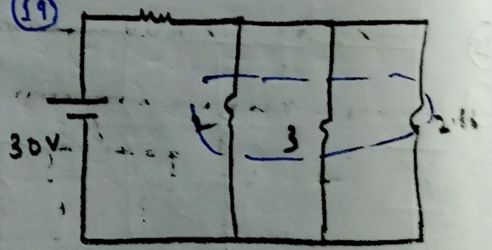

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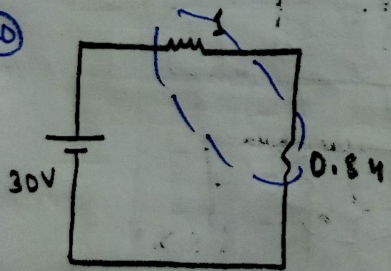

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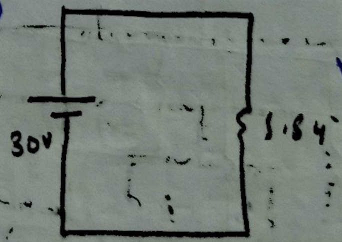
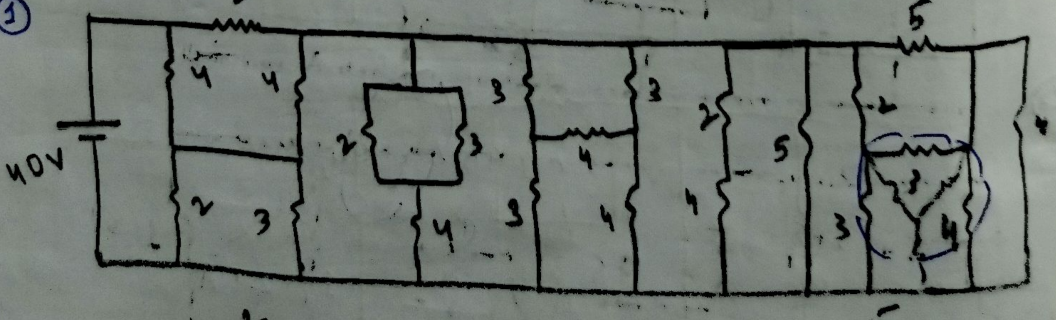


$V = 30V$; $R = 1.84$

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

$I = \frac{30}{1.84} = 16.3A$

9) (1)



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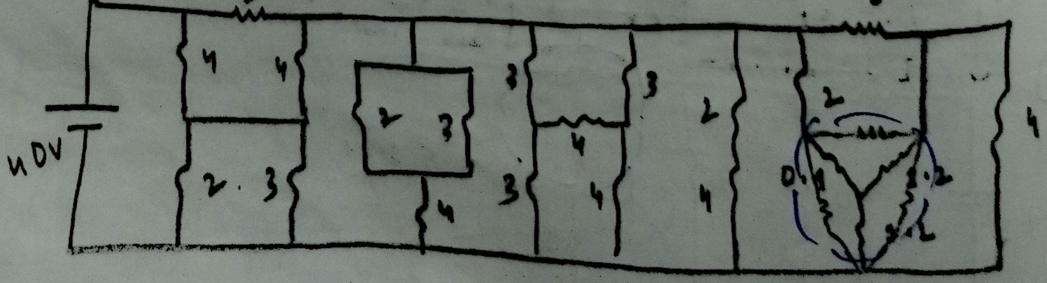

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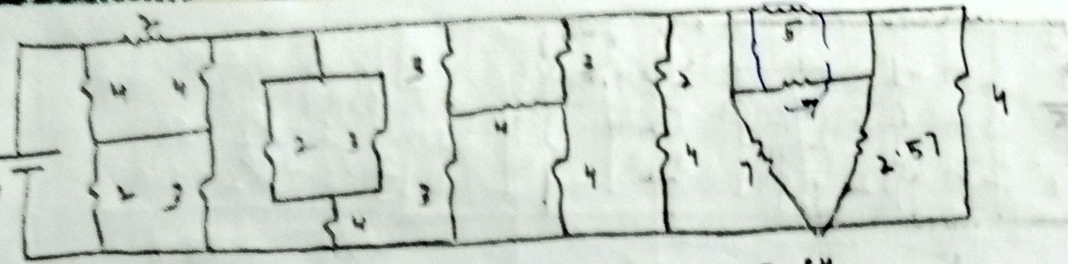
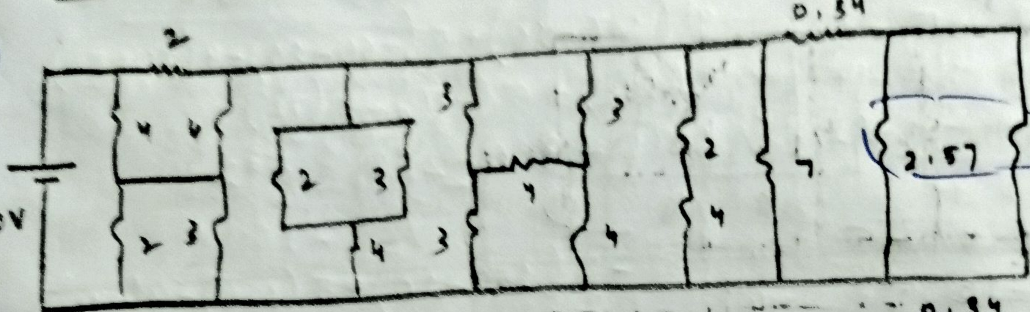
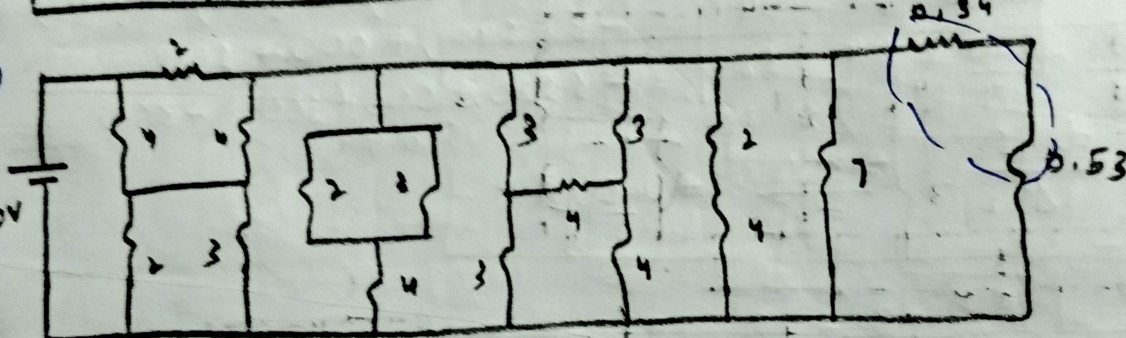

40V
2
4 4
2 3
2 3
4
3
3
4
3
4
2
4
5
7
7
2.57
4

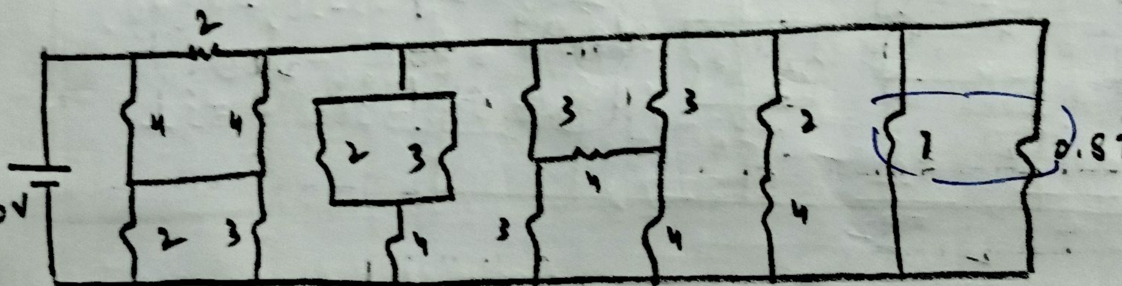
4


2
0.34
40V
4 4
2 3
2 3
4
3
3
4
3
4
2
4
7
2.57
4

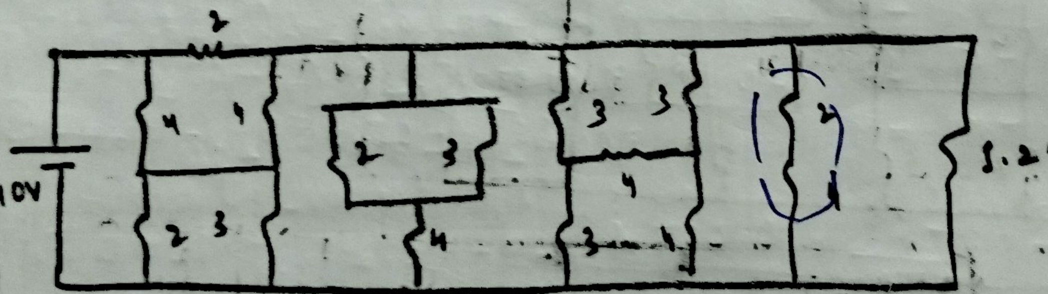
5


2
0.34
40V
4 4
2 3
2 3
4
3
3
4
3
4
2
4
7
0.53

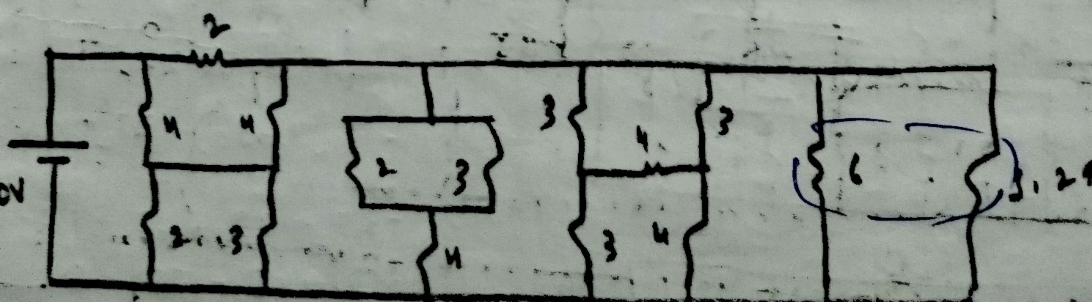
6


2
40V
4 4
2 3
2 3
4
3
3
3
4
4
2
4
7
0.57

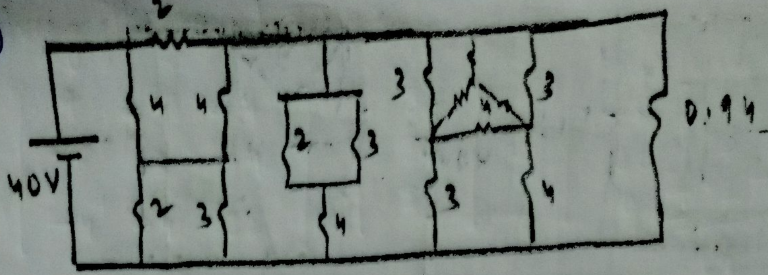
7


2
40V
4 4
2 3
2 3
4
3 3
4
3 4
2
1.29

8


2
40V
4 4
2 3
2 3
4
3
4
3
3 4
6
1.29

9



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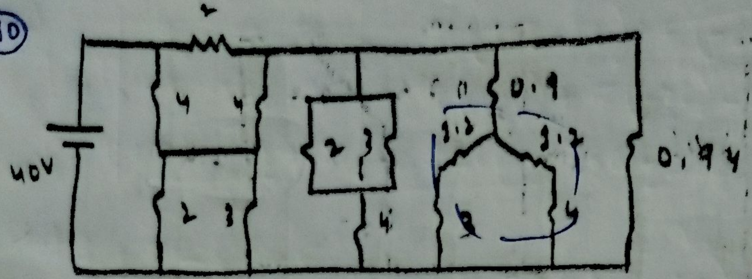

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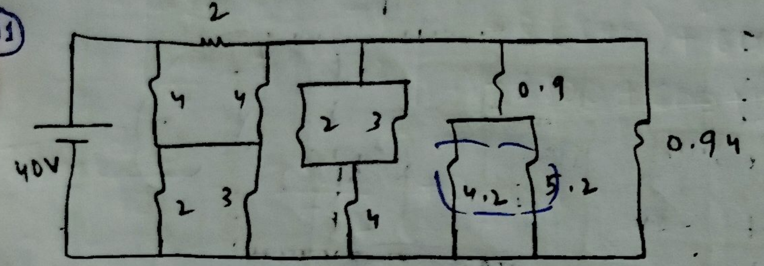

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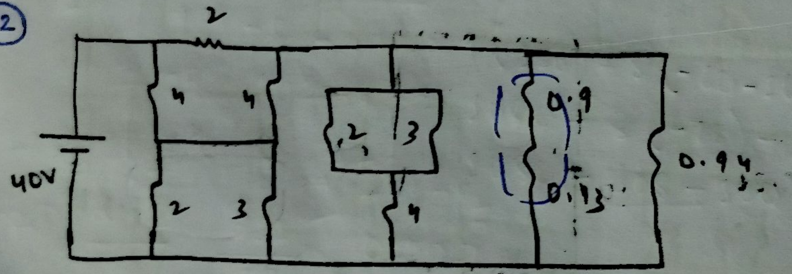

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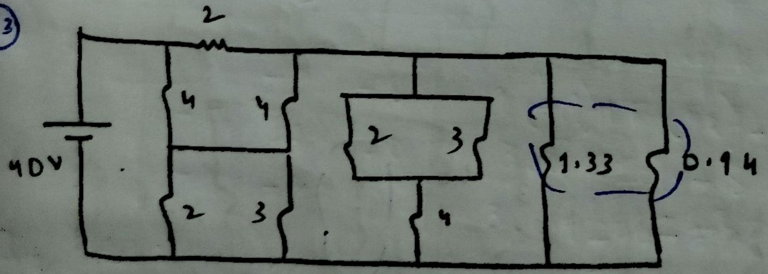

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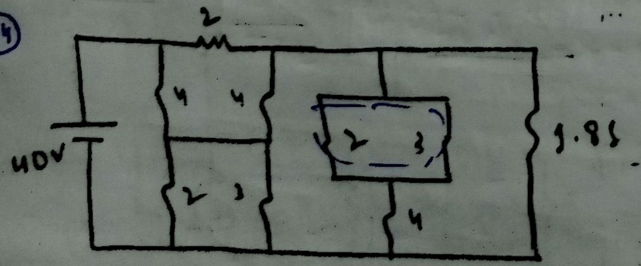

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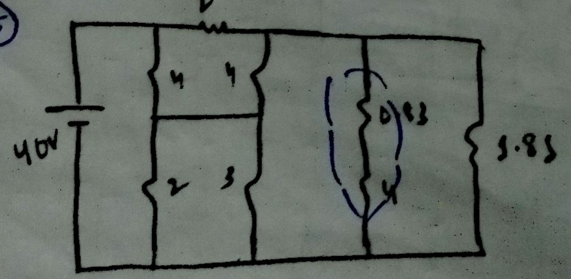

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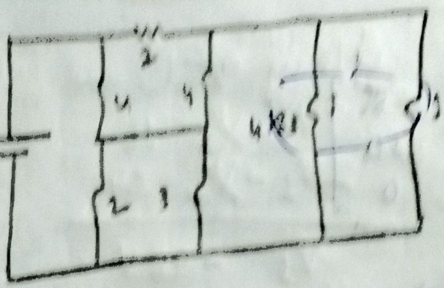

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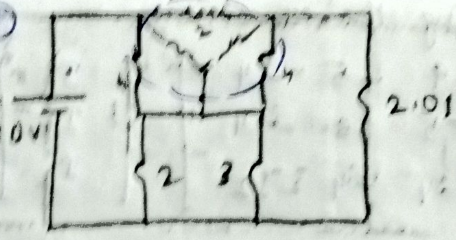

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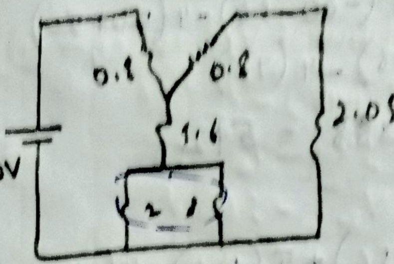

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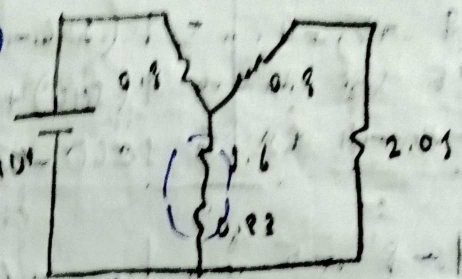

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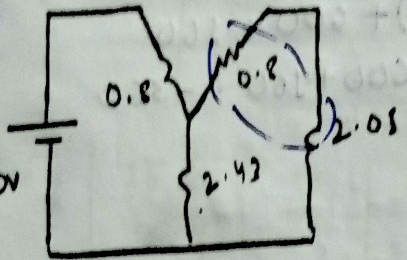

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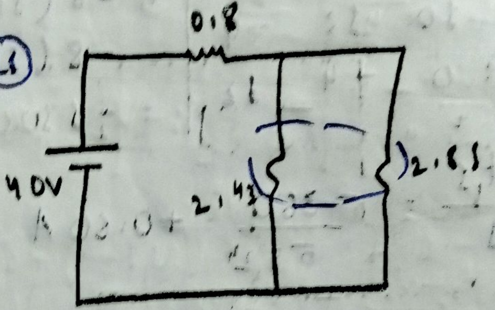

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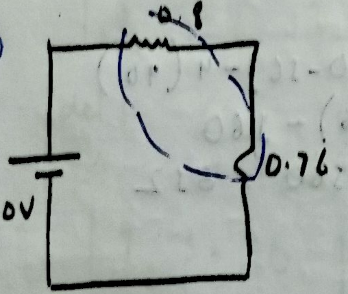

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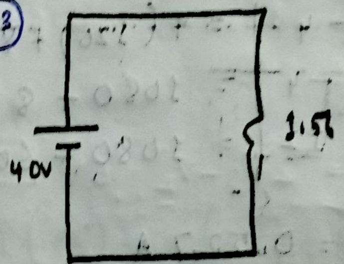


$V = 40\,V$; $R = 1.56\,\Omega$

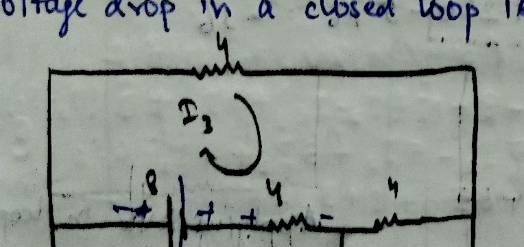
$V = IR \Rightarrow I = \frac{V}{R}$

$I = \frac{40}{1.56} = 25.64\,A$

KVL and KCL

KVL :-

Voltage drop in a closed loop is always zero.



Applying KVL in loop 1,

$-10 + 8 + 4(I_1 - I_3) + 5(I_1 - I_2) = 0$

$-10 + 8 + 4I_1 - 4I_3 + 5I_1 - 5I_2 = 0$

$9I_1 - 5I_2 - 4I_3 = -8$ —— (i)

Applying KVL in loop 2,

$-10 + 4(I_2 - I_3) + 4I_2 + 5(I_2 - I_1) = 0$

$-10 + 4I_2 - 4I_3 + 4I_2 + 5I_2 - 5I_1 = 0$

$-5I_1 + 13I_2 - 4I_3 = 10$ —— (ii)

Applying KVL in loop 3,

$-8 + 4I_3 + 4(I_3 - I_2) + 4(I_3 - I_1) = 0$

$-8 + 4I_3 + 4I_3 - 4I_2 + 4I_3 - 4I_1 = 0$

$-4I_1 - 4I_2 + 12I_3 = 0$ —— (iii)

Solving the equations,

$$\begin{bmatrix} 9 & -5 & -4 \\ -5 & 13 & -4 \\ -4 & -4 & 12 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} -8 \\ 10 \\ 0 \end{bmatrix}$$

$$\Delta = \begin{vmatrix} 9 & -5 & -4 \\ -5 & 13 & -4 \\ -4 & -4 & 12 \end{vmatrix} = 9(156-16)+5(-60-16)-4(20+52)$$
$$= 9(140)+5(-76)-4(72)$$
$$= 1260-380-288 = 592$$

$$\det 1 = \begin{vmatrix} -8 & -5 & -4 \\ 10 & 13 & -4 \\ 0 & -4 & 12 \end{vmatrix} = -8(156-16)+5(120)-4(-40)$$
$$= -8(140)+600+160$$
$$= -1120+600+160 = -360$$

$$I_1 = \frac{\det 1}{\Delta} = \frac{-360}{592} = +0.60\text{ A}$$

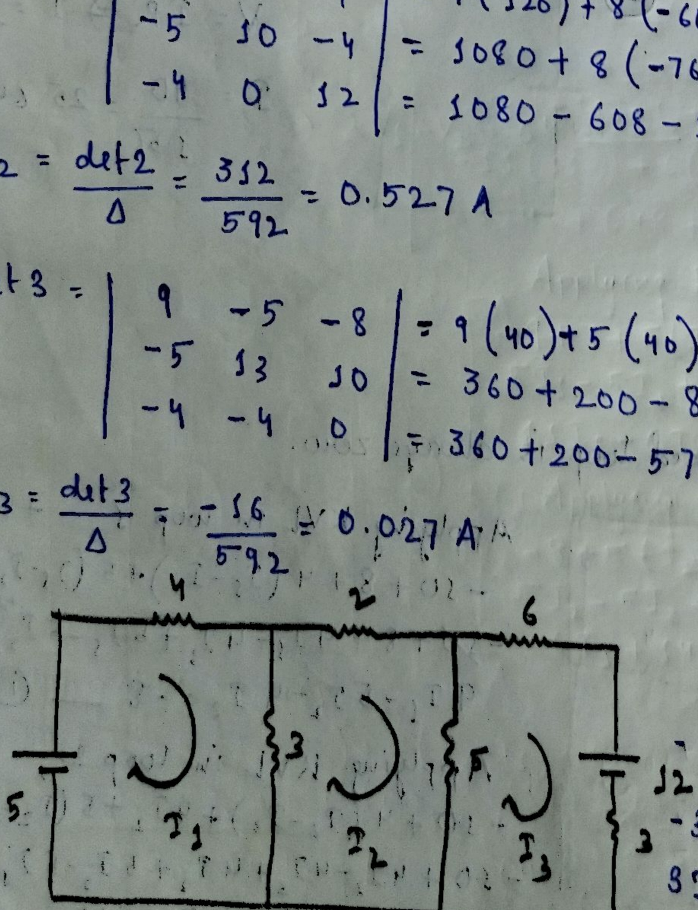
$$\det 2 = \begin{vmatrix} 9 & -8 & -4 \\ -5 & 10 & -4 \\ -4 & 0 & 12 \end{vmatrix} = 9(120)+8(-60-16)-4(40)$$
$$= 1080+8(-76)-160$$
$$= 1080-608-160 = 312$$

$$I_2 = \frac{\det 2}{\Delta} = \frac{312}{592} = 0.527\text{ A}$$

$$\det 3 = \begin{vmatrix} 9 & -5 & -8 \\ -5 & 13 & 10 \\ -4 & -4 & 0 \end{vmatrix} = 9(40)+5(40)-8(20+52)$$
$$= 360+200-8(72)$$
$$= 360+200-576 = -16$$

$$I_3 = \frac{\det 3}{\Delta} = \frac{-16}{592} = 0.027\text{ A}$$

9)



Applying KVL in loop 2

$-3(I_2-I_1)+2I_2+5(I_2-$

$-3I_2+3I_1+2I_2+5I_2-5I_3$

$3I_1+4I_2-5I_3=0$ — (

Applying KVL in loop 1,

$-15+4I_1+3(I_1-I_2)=0$

$-15+4I_1+3I_1-3I_2=0$

$7I_1-3I_2=15$ —— ①

Applying KVL in loop 3,

$-12 + 3I_3 + 5(I_3 - I_2) + 6I_3 = 0$

$3I_3 + 15I_3 - 5I_2 + 6I_3 = 12$

$14I_3 - 5I_2 = 12$ ——— (iii)

Solving the equations,

$$\begin{bmatrix} 7 & -3 & 0 \\ 3 & 4 & -5 \\ 0 & -5 & 14 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} 15 \\ 0 \\ 12 \end{bmatrix}$$

$$\Delta = \begin{vmatrix} 7 & -3 & 0 \\ 3 & 4 & -5 \\ 0 & -5 & 14 \end{vmatrix} \begin{aligned} &= 7(56-25) + 3(42) \\ &= 7(31) + 3(42) \\ &= 217 + 126 = 343 \end{aligned}$$

$$\det 1 = \begin{vmatrix} 15 & -3 & 0 \\ 0 & 4 & -5 \\ 12 & -5 & 14 \end{vmatrix} \begin{aligned} &= 15(56-25) + 3(60) \\ &= 15(31) + 180 \\ &= 465 + 180 = 645 \end{aligned}$$

$$I_1 = \frac{\det 1}{\Delta} = \frac{645}{343} = 1.88\ A$$

$$\det 2 = \begin{vmatrix} 7 & 15 & 0 \\ 3 & 0 & -5 \\ 0 & 12 & 14 \end{vmatrix} \begin{aligned} &= 7(60) - 15(42) + 0 \\ &= 420 - 630 \\ &= -210 \end{aligned}$$

$$I_2 = \frac{\det 2}{\Delta} = \frac{-210}{343} = 0.612\ A$$

$$\det 3 = \begin{vmatrix} 7 & -3 & 15 \\ 3 & 4 & 0 \\ 0 & -5 & 12 \end{vmatrix} \begin{aligned} &= 7(48) + 3(36) + 15(-15) \\ &= 336 + 108 - 225 \\ &= 219 \end{aligned}$$

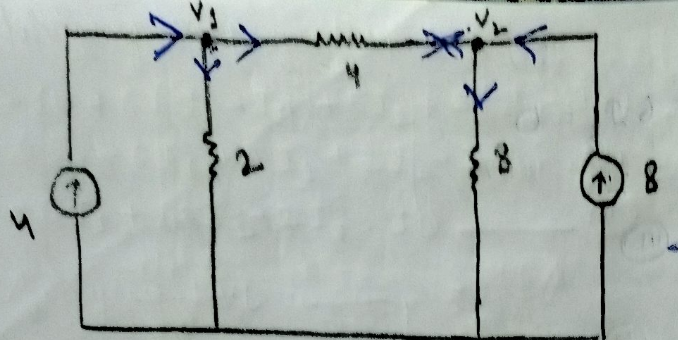
$$I_3 = \frac{\det 3}{\Delta} = \frac{219}{343} = 0.638\ A$$

KCL :-

Current entering the node = Current leaving the node

Prerequisite assumption,

Current entering = $-ve$ }
Current leaving = $+ve$ } Assumed by us



Solving eq^n (i) and (ii),

$$3V_1 - V_2 = 16$$
$$2V_1 - V_2 = 64$$
$$V_1 = -48\,V$$

Putting 'V_1' in eq^n (i),

$$3(-48) - V_2 = 16$$
$$-144 - V_2 = 16$$
$$V_2 = -160\,V$$

Applying KCL at node 1,

$$-4 + \frac{V_1 - 0}{2} + \frac{V_1 - V_2}{4} = 0$$

$$-4 + \frac{V_1}{2} + \frac{V_1}{4} - \frac{V_2}{4} = 0$$

$$\frac{3V_1}{4} - \frac{V_2}{4} = 4 \Rightarrow 3V_1 - V_2 = 16 \longrightarrow \text{(i)}$$

Applying KCL at node 2,

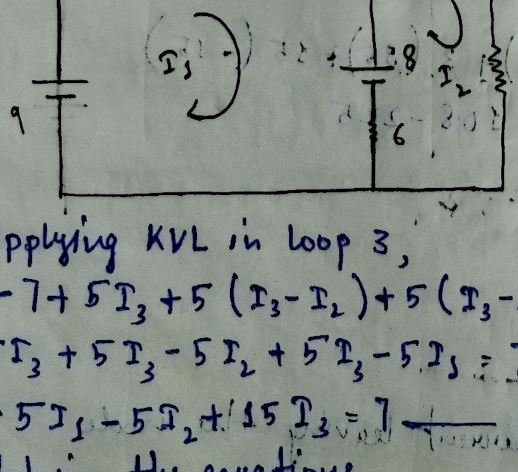
$$-8 - \frac{(V_2 - V_1)}{4} + \frac{V_2 - 0}{8} = 0$$

$$-8 - \frac{V_2}{4} + \frac{V_1}{4} + \frac{V_2}{8} = 0$$

$$-\frac{V_2}{8} + \frac{2V_1}{8} = 8 \Rightarrow 2V_1 - V_2 = 64 \longrightarrow \text{(ii)}$$

H.W (3)

1)



Applying KVL in loop 1,

$$-9 + 7 + 5(I_1 - I_3) + 8 + 6(I_1 - I_2) = 0$$
$$5I_1 - 5I_3 + 6I_1 - 6I_2 = -6$$
$$11I_1 - 6I_2 - 5I_3 = -6 \longrightarrow \text{(i)}$$

Applying KVL in loop 2,

$$-8 + 5(I_2 - I_3) + 3I_2 + 6(I_2 - I_1) = 0$$
$$5I_2 - 5I_3 + 3I_2 + 6I_2 - 6I_1 = 8$$
$$-6I_1 + 14I_2 - 5I_3 = 8 \longrightarrow \text{(ii)}$$

Applying KVL in loop 3,

$$-7 + 5I_3 + 5(I_3 - I_2) + 5(I_3 - I_1) = 0$$
$$5I_3 + 5I_3 - 5I_2 + 5I_3 - 5I_1 = 7$$
$$-5I_1 - 5I_2 + 15I_3 = 7 \longrightarrow \text{(iii)}$$

Solving the equations,

P.T.O

$$\begin{bmatrix} 11 & -6 & -5 \\ -6 & 14 & -5 \\ -5 & -5 & 15 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} -6 \\ 8 \\ 7 \end{bmatrix}$$

$$\Delta = \begin{vmatrix} 11 & -6 & -5 \\ -6 & 14 & -5 \\ -5 & -5 & 15 \end{vmatrix} = 11(210-25)+6(-90-25)-5(30+70)$$
$$= 11(185)+6(-115)-5(100)$$
$$= 2035-690-500 = 845$$

$$\det 1 = \begin{vmatrix} -6 & -6 & -5 \\ 8 & 14 & -5 \\ 7 & -5 & 15 \end{vmatrix} = -6(210-25)+6(120+35)-5(-40-98)$$
$$= -6(185)+6(155)-5(-138)$$
$$= -1110+930+690 = 510$$

$$I_1 = \frac{\det 1}{\Delta} = \frac{510}{845} = 0.60\,A$$

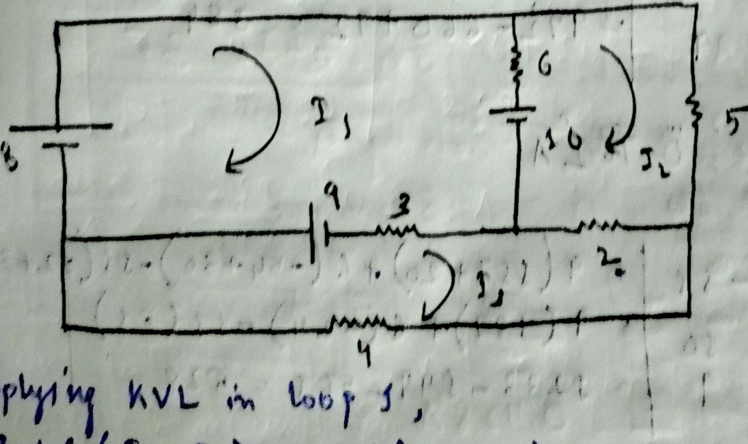
$$\det 2 = \begin{vmatrix} 11 & -6 & -5 \\ -6 & 8 & -5 \\ 5 & 7 & 15 \end{vmatrix} = 11(120+35)+6(-90+25)-5(-90+25)$$
$$= 11(155)+6(-65)-5(-65)$$
$$= 1705-390+325 = 1640$$

$$I_2 = \frac{\det 2}{\Delta} = \frac{1640}{845} = 1.94\,A$$

$$\det 3 = \begin{vmatrix} 11 & -6 & -6 \\ -6 & 14 & 8 \\ 5 & -5 & 7 \end{vmatrix} = 11(98+40)+6(-42-40)-6(30-70)$$
$$= 11(138)+6(-82)-6(-40)$$
$$= 1518-492+240 = 1266$$

$$I_3 = \frac{\det 3}{\Delta} = \frac{1266}{845} = 1.498\,A$$

9)



Applying KVL in loop 1,

$$-8+6(I_1-I_2)+10+3(I_1-I_3)+9 = 0$$
$$-8+6I_1-6I_2+10+3I_1-3I_3+9 = 0$$
$$9I_1-6I_2-3I_3 = -11 \quad \text{——} \quad (1)$$

Applying KVL in loop 2,

$-10 + 6(I_2 - I_1) + 5I_2 + 2(I_2 - I_3) = 0$

$6I_2 - 6I_1 + 5I_2 + 2I_2 - 2I_3 = 10$

$-6I_1 + 13I_2 - 2I_3 = 10$ ———— (ii)

Applying KVL in loop 3,

$-9 + 3(I_3 - I_1) + 2(I_3 - I_2) + 4I_3 = 0$

$3I_3 - 3I_1 + 2I_3 - 2I_2 + 4I_3 = 9$

$-3I_1 - 2I_2 + 9I_3 = 9$ ———— (iii)

Solving the equations,

$$\begin{bmatrix} 9 & -6 & -3 \\ -6 & 13 & -2 \\ -3 & -2 & 9 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} -11 \\ 10 \\ 9 \end{bmatrix}$$

$$\Delta = \begin{vmatrix} 9 & -6 & -3 \\ -6 & 13 & -2 \\ -3 & -2 & 9 \end{vmatrix} = 9(117-4) + 6(-54-6) - 3(12+39)$$
$$= 9(113) + 6(-60) - 3(51)$$
$$= 1017 - 360 - 153 = 504$$

$$\det 1 = \begin{vmatrix} -11 & -6 & -3 \\ 10 & 13 & -2 \\ 9 & -2 & +9 \end{vmatrix} = -11(+117-4) + 6(90+18) - 3(-20-117)$$
$$= -11(113) + 6(108) - 3(-137)$$
$$= -1243 + 648 + 411 = |-184| = 184$$

$$I_1 = \frac{\det 1}{\Delta} = \frac{184}{504} = 0.365\,A$$

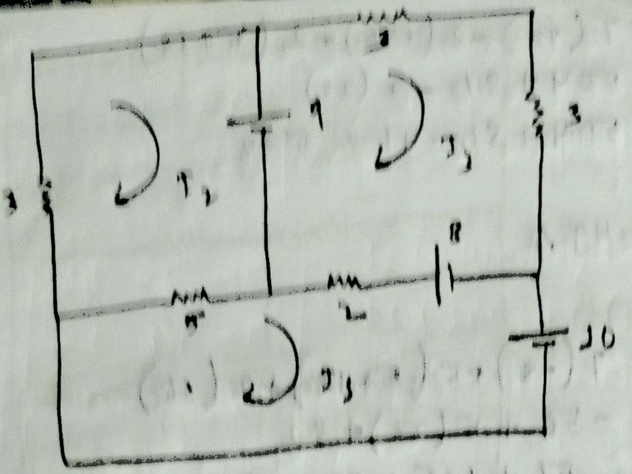
$$\det 2 = \begin{vmatrix} 9 & -11 & -3 \\ -6 & 10 & -2 \\ -3 & 9 & 9 \end{vmatrix} = 9(90+18) + 11(-54-6) - 3(-54+30)$$
$$= 9(108) + 11(-60) - 3(-24)$$
$$= 972 - 660 + 72 = 384$$

$$I_2 = \frac{\det 2}{\Delta} = \frac{384}{504} = 0.762\,A$$

$$\det 3 = \begin{vmatrix} 9 & -6 & -11 \\ -6 & 13 & 10 \\ -3 & -2 & 9 \end{vmatrix} = 9(117+20) + 6(-54+30) - 11(12+39)$$
$$= 9(137) + 6(-24) - 11(51)$$
$$= 1233 - 144 - 561 = 528$$

$$I_3 = \frac{\det 3}{\Delta} = \frac{528}{504} = 1.047\,A$$

7)



Applying KVL in loop 1,

$-10 + 5(I_1 - I_2) + 2(I_1 - I_3) + 8 = 0$

$5I_1 - 5I_2 + 2I_1 - 2I_3 = 2$

$7I_1 - 5I_2 - 2I_3 = 2$ ——— (i)

Applying KVL in loop 2,

$-9 + 5(I_2 - I_1) + 3I_2 = 0$

$5I_2 - 5I_1 + 3I_2 = 9$

$-5I_1 + 8I_2 = 9$ ——— (ii)

Applying KVL in loop 3,

$-8 + 2(I_3 - I_1) + 9 + 3I_3 + 3I_3 = 0$

$2I_3 - 2I_1 + 3I_3 + 3I_3 = -1$

$-2I_1 + 8I_3 = -1$ ——— (iii)

Solving the equations,

$$\begin{bmatrix} 7 & -5 & -2 \\ -5 & 8 & 0 \\ -2 & 0 & 8 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} 2 \\ 9 \\ -1 \end{bmatrix}$$

$$\Delta = \begin{vmatrix} 7 & -5 & -2 \\ -5 & 8 & 0 \\ -2 & 0 & 8 \end{vmatrix} = 7(64) + 5(-40) - 2(16)$$

$= 448 - 200 - 32$

$= 216$

$$\det 1 = \begin{vmatrix} 2 & -5 & -2 \\ 9 & 8 & 0 \\ -1 & 0 & 8 \end{vmatrix} = 2(64) + 5(72) - 2(8)$$

$= 128 + 360 - 16$

$= 472$

$$I_1 = \frac{\det 1}{\Delta} = \frac{472}{216} = 2.185\,A$$

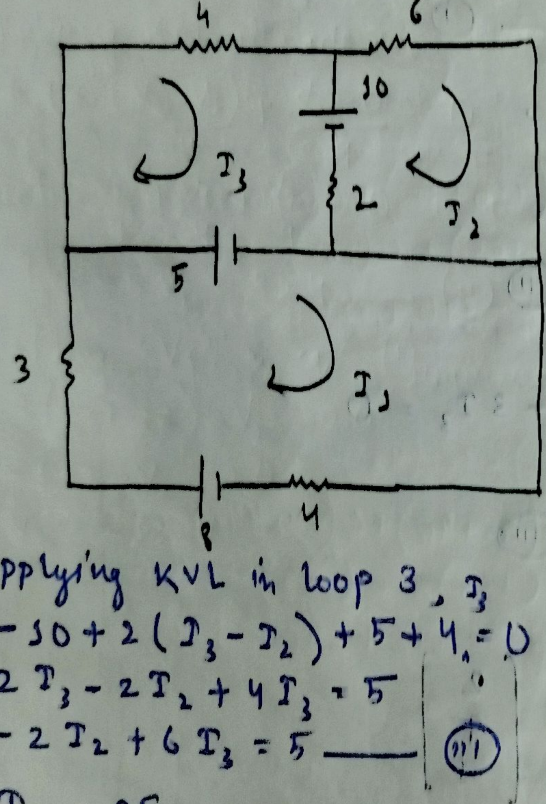
$$\det 2 = \begin{vmatrix} 7 & 2 & -2 \\ -5 & 9 & 0 \\ -2 & -1 & 8 \end{vmatrix} = 7(72) - 2(-40) - 2(5+18) = 504 + 80 - 2(23) = 504 + 80 - 46 = 538$$

$$I_2 = \frac{\det 2}{\Delta} = \frac{538}{216} = 2.49\ A$$

$$\det 3 = \begin{vmatrix} 7 & -5 & 2 \\ -5 & 8 & 9 \\ -2 & 0 & -1 \end{vmatrix} = 7(-8) + 5(5+18) + 2(16) = -56 + 5(23) + 32 = -56 + 115 + 32 = 91$$

$$I_3 = \frac{\det 3}{\Delta} = \frac{91}{216} = 0.421\ A$$

Q)



Applying KVL in loop 1,

$-5 + 4I_1 + 8 + 3I_1 = 0$

$7I_1 = -3 \Rightarrow I_1 = \left|-\frac{3}{7}\right| = \frac{3}{7}$

Applying KVL in loop 2,

$-10 + 6I_2 + 2(I_2 - I_3) = 0$

$6I_2 + 2I_2 - 2I_3 = 10$

$8I_2 - 2I_3 = 10$ —— (ii)

Applying KVL in loop 3, I_3

$-10 + 2(I_3 - I_2) + 5 + 4 = 0$

$2I_3 - 2I_2 + 4I_3 = 5$

$-2I_2 + 6I_3 = 5$ —— (iii)

$I_2 = \frac{35}{22} = 1.59\ A$

Solving eq$^{\underline{n}}$ (ii) and (iii)

$[8I_2 - 2I_3 = 10] \times 3$

$-2I_2 + 6I_3 = 5$

$24I_2 - 6I_3 = 30$

$-2I_2 + 6I_3 = 5$

$22I_2 = 35$

Substituting (I_2) in eq$^{\underline{n}}$ (ii),

$8(1.59) - 2I_3 = 10$

$12.72 - 2I_3 = 10$

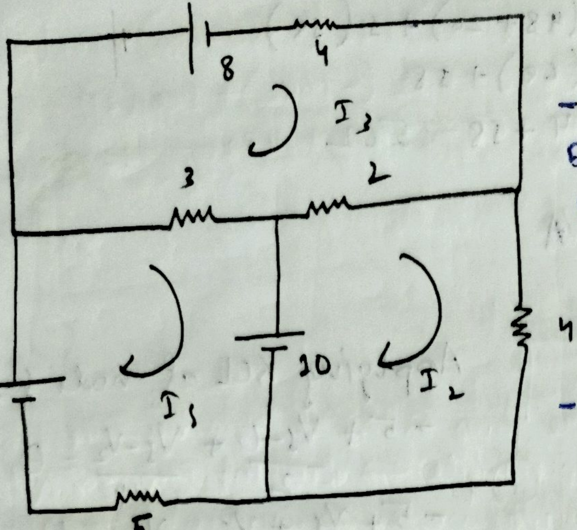
$\cancel{1}2I_3 = \cancel{1}2.72 \Rightarrow I_3 = \frac{2.72}{2} = 1.36\ A$

From eq$^{\underline{n}}$ (i), $I_1 = \frac{3}{7} = 0.428\ A$

And, $I_2 = 1.59\ A$

$I_3 = 1.36\ A$

8)



Applying KVL in loop 1,

$-10+5I_1+9+3(I_1-I_3)=0$

$5I_1+3I_1-3I_3=1$

$8I_1-3I_3=1$ ——— (i)

Applying KVL in loop 2,

$-10+2(I_2-I_3)+4I_2=0$

$-10+2I_2-2I_3+4I_2=0$

$6I_2-2I_3=10$ ——— (ii)

Applying KVL in loop 3,

$-8+4I_3+2(I_3-I_2)+3(I_3-I_1)=0$

$4I_3+2I_3-2I_2+3I_3-3I_1=8$

$-3I_1-2I_2+9I_3=8$ ——— (iii)

Solving the equations,

$$\begin{bmatrix} 8 & 0 & -3 \\ 0 & 6 & -2 \\ -3 & -2 & 9 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} 1 \\ 10 \\ 8 \end{bmatrix}$$

$$\Delta = \begin{vmatrix} 8 & 0 & -3 \\ 0 & 6 & -2 \\ -3 & -2 & 9 \end{vmatrix} = 8(54-4)-3(18) = 8(50)-3(18) = 400-54 = 846$$

$$\det 1 = \begin{vmatrix} 1 & 0 & -3 \\ 10 & 6 & -2 \\ 8 & -2 & 9 \end{vmatrix} = 1(54-4)-3(-20-48) = 50-3(-68) = 50+204 = 254$$

$$I_1 = \frac{\det 1}{\Delta} = \frac{254}{346} = 0.734\text{ A}$$

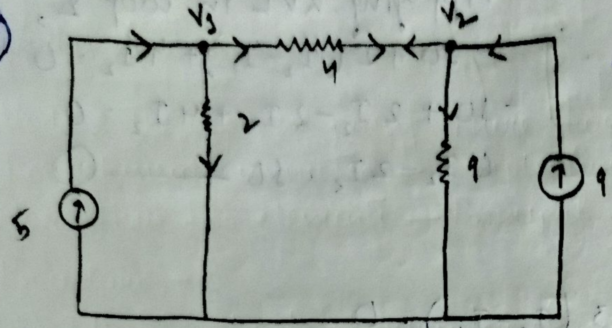
$$\det 2 = \begin{vmatrix} 8 & 1 & -3 \\ 0 & 10 & -2 \\ -3 & 8 & 9 \end{vmatrix} = 8(90+16)-1(-6)-3(30) = 8(105)+6-90 = 840+6-90 = 756$$

$$I_2 = \frac{\det 2}{\Delta} = \frac{756}{346} = 2.185\text{ A}$$

$$\Delta_3 = \begin{vmatrix} 8 & 0 & 1 \\ 0 & 6 & 10 \\ -3 & -2 & 8 \end{vmatrix} = 8(48+20)+1(18) = 8(68)+18 = 544+18 = 562$$

$$I_3 = \frac{\det 3}{\Delta} = \frac{562}{346} = 1.624\,A$$

Q)



Applying KCL at node 1,

$$-5 + \frac{V_1 - 0}{2} + \frac{V_1 - V_2}{4} = 0$$

$$-5 + \frac{V_1}{2} + \frac{V_1}{4} - \frac{V_2}{4} = 0$$

$$3V_1 - V_2 = 20 \quad \text{——— (i)}$$

Applying KCL at node 2,

$$-9 - \frac{(V_2 - V_1)}{4} + \frac{V_2 - 0}{9} = 0$$

$$-9 - \frac{V_2}{4} + \frac{V_1}{4} + \frac{V_2}{9} = 0$$

$$9V_1 - 5V_2 = 324 \quad \text{——— (ii)}$$

Solving eq^n (i) and (ii),

$$15V_1 - \cancel{5V_2} = 100$$
$$9V_1 - \cancel{5V_2} = 324$$

$$6V_1 = -224$$

$$V_1 = -\frac{224}{6} = -37.33\,V$$

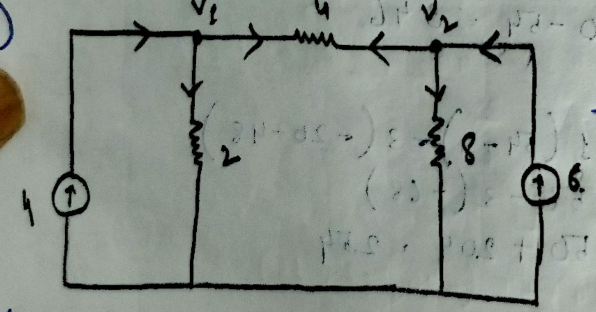
Putting 'V_1' in eq^n (i),

$$3(-37.33) - V_2 = 20$$

$$-112 - V_2 = 20$$

$$V_2 = -132\,V$$

Q)



Applying KCL at node 1,

$$-4 + \frac{V_1 - 0}{2} + \frac{V_1 - V_2}{4} = 0$$

$$-4 + \frac{V_1}{2} + \frac{V_1}{4} - \frac{V_2}{4} = 0$$

$$3V_1 - V_2 = 16 \quad \text{——— (i)}$$

Applying KCL at node 2,

$$-6 - \frac{(V_2 - V_1)}{4} + \frac{V_2 - 0}{8} = 0$$

$$-6 - \frac{V_2}{4} + \frac{V_1}{4} + \frac{V_2}{8} = 0$$

$$2V_1 - V_2 = 48 \quad \text{——— (ii)}$$

Solving eq^n (i) and (ii),

$$3V_1 - \cancel{V_2} = 16$$
$$2V_1 - \cancel{V_2} = 48$$

$$V_1 = -32\,V$$

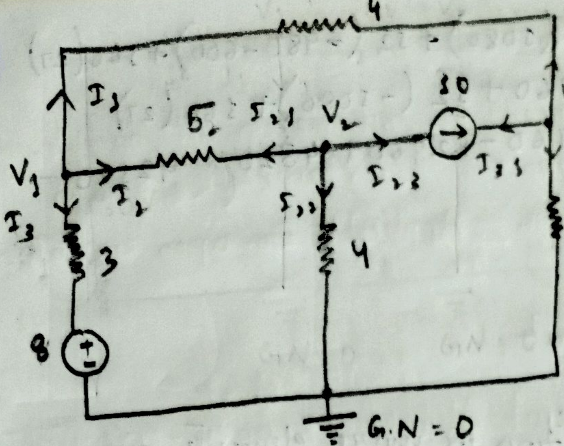
Putting 'V_1' in eq^n (i),

$$3(-32) - V_2 = 16$$

$$-96 - V_2 = 16$$

$$V_2 = -112\,V$$

Q)



Applying KCL at node 1,

$$I_1 + I_2 + I_3 = 0$$

$$\frac{V_1 - V_3}{4} + \frac{V_1 - V_2}{5} + \frac{V_1 - 0 - 8}{3} = 0$$

$$\frac{V_1}{4} - \frac{V_3}{4} + \frac{V_1}{5} - \frac{V_2}{5} + \frac{V_1}{3} = \frac{8}{3}$$

$$47V_1 - 12V_2 - 15V_3 = 160 \quad \text{— (i)}$$

Applying KCL at node 3,

$$I_{31} + I_{32} + I_{33} = 0$$

$$-10 + \frac{V_3 - V_1}{4} + \frac{V_3 - 0}{3} = 0$$

$$\frac{V_3}{4} - \frac{V_1}{4} + \frac{V_3}{3} = 10$$

$$-3V_1 + 7V_3 = 120 \quad \text{— (iii)}$$

Applying KCL at node 2,

$$I_{21} + I_{22} + I_{23} = 0$$

$$\frac{V_2 - V_1}{5} + \frac{V_2 - 0}{4} + 10 = 0$$

$$\frac{V_2}{5} - \frac{V_1}{5} + \frac{V_2}{4} = -10$$

$$-4V_1 + 9V_2 = -200 \quad \text{— (ii)}$$

Solving the equations,

$$\begin{bmatrix} 47 & -12 & -15 \\ -4 & 9 & 0 \\ -3 & 0 & 7 \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ V_3 \end{bmatrix} = \begin{bmatrix} 160 \\ -200 \\ 120 \end{bmatrix}$$

$$\Delta = \begin{vmatrix} 47 & -12 & -15 \\ -4 & 9 & 0 \\ -3 & 0 & 7 \end{vmatrix} = 47(63) + 12(-28) - 15(27) = 2961 - 336 - 405 = 2220$$

$$\det 1 = \begin{vmatrix} 160 & -12 & -15 \\ -200 & 9 & 0 \\ 120 & 0 & 7 \end{vmatrix} = 160(63) + 12(-1400) - 15(-1080) = 10080 - 16800 + 16200 = 9480$$

$$V_1 = \frac{\det 1}{\Delta} = \frac{9480}{2220} = 4.27\,V$$

$$\det 2 = \begin{vmatrix} 47 & 160 & -15 \\ -4 & -200 & 0 \\ -3 & 120 & 7 \end{vmatrix} = 47(-1400) - 160(-28) - 15(-480 - 600)$$
$$= -65800 + 4480 - 15(-1080)$$
$$= -65800 + 4480 + 16200 = -45120$$

$$V_2 = \frac{\det 2}{\Delta} = \frac{-45120}{2220} = -20.324\,V$$

$$\det 3 = \begin{vmatrix} 47 & -12 & 160 \\ -4 & 9 & -200 \\ -3 & 0 & 120 \end{vmatrix} = 47(1080) + 12(-480-600) + 160(27)$$
$$= 50760 + 12(-1080) + 160(27)$$
$$= 50760 - 12960 + 4320 = 42120$$

$$V_3 = \frac{\det 3}{\Delta} = \frac{42120}{2220} = 18.972\,V$$

Nodal Analysis :-

Node : The common point where two or more elements are conne[cted]
Two elements connected – Simple node → Current Division ✗
More than two elements – Principal node → Current Division ✓

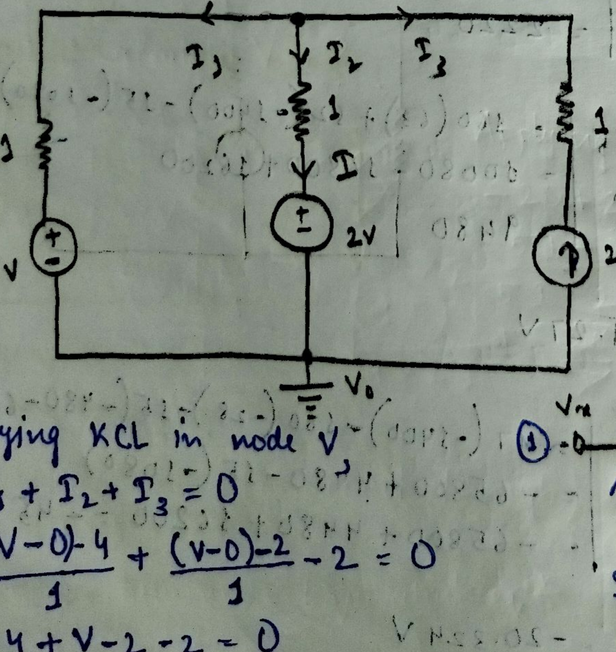
Procedure :-

(I) Identify the total number of nodes.
(II) Assign the voltage at each node. One node is taken as refer[ence] node (datum), potential taken as 0 V.
(III) Develop the KCL equations for each non-reference node.
(IV) Solve the KCL equations to get the node voltage.

NOTE :-

(i) Applicable for both planar and non-planar networks.
(ii) Number of equations required to solve an electrical network is, $e = N - 1$

Q) Find the value of current I using nodal analysis.



No. of nodes = 2
V_0 = Reference node = 0 V
V = Non-Reference node

Important cases for finding current directly :-

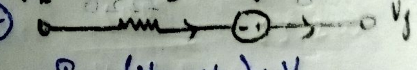
Applying KCL in node V,

$$I_1 + I_2 + I_3 = 0$$
$$\frac{(V-0)-4}{1} + \frac{(V-0)-2}{1} - 2 = 0$$
$$V - 4 + V - 2 - 2 = 0$$
$$2V = 8$$
$$V = \frac{8}{2} = 4V$$

$$I = I_2 = \frac{V-2}{1}$$
$$I = 4 - 2 = 2A \text{ (Ans)}$$

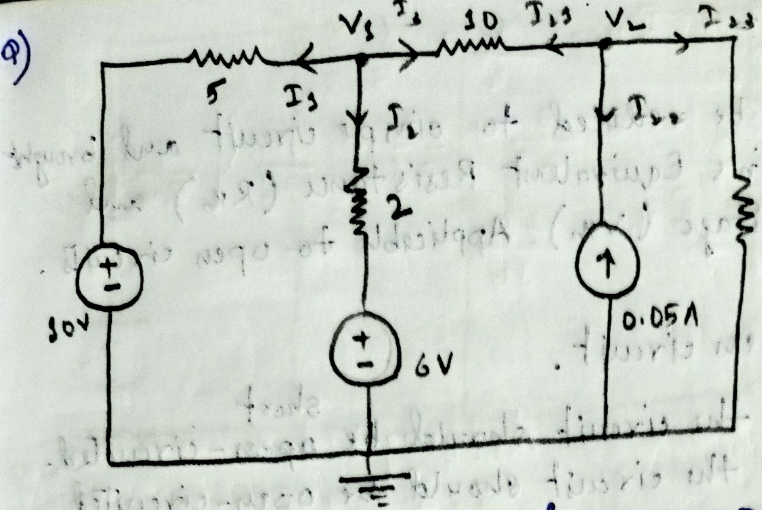
① 

Applying KVL,
$$V_x - IR - V = V_y$$
$$I = \frac{(V_x - V_y) - V}{R}$$

② 

$$I = \frac{(V_x - V_y) + V}{R}$$

Q)



Applying KCL in node 1, $[I_1 + I_2 + I_3 = 0]$

$$\frac{(V_1 - 0) - 10}{5} + \frac{(V_1 - 0) - 6}{2} + \frac{(V_1 - V_2)}{10}$$

$$\frac{V_1}{5} - 2 + \frac{V_1}{2} - 3 + \frac{V_1}{10} - \frac{V_2}{10} = 0$$

$$8V_1 - V_2 = 50 \text{ ——— (i)}$$

Applying KCL in node 2, $[I_{21} + I_{22} + I_{23} = 0]$

$$\frac{(V_2 - V_1)}{10} + \frac{(V_2 - 0)}{4} - 0.05 = 0$$

$$\frac{V_2}{10} - \frac{V_1}{10} + \frac{V_2}{4} = 0.05$$

$$-2V_1 + 7V_2 = 1 \text{ ——— (ii)}$$

Solving eq^n (i) and (ii),

$$8V_1 - V_2 = 50$$
$$-8V_1 + 28V_2 = 4$$

$$27V_2 = 54$$

$$V_2 = \frac{54}{27} = 2V$$

Putting 'V_2' in eq^n (ii),

$$-2V_1 + 7(2) = 1$$
$$-2V_1 = -13$$
$$V_1 = \frac{13}{2} = 6.5V$$

Theminin's Theorem :-

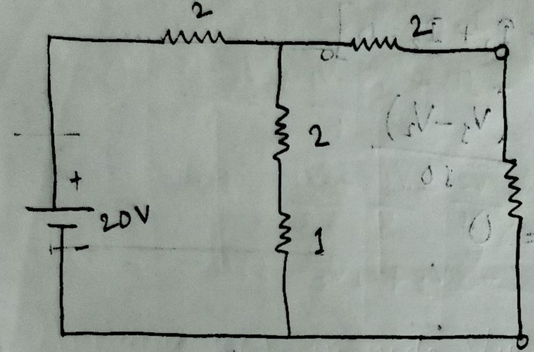
Any complex circuit can be reduced to simple circuit and brou to the form of Thevinin's Equivalent Resistance (R_{th}) and Thevinin's Equivalent Voltage (V_{th}). Applicable to open circuits.

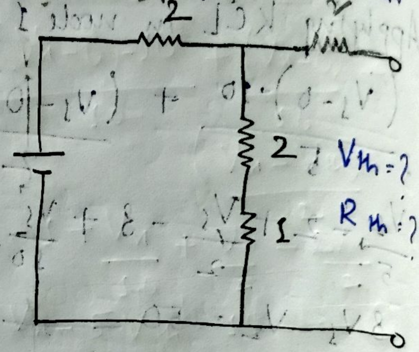
Conditions for R_{th} :-

(I) The load should be open circuit.

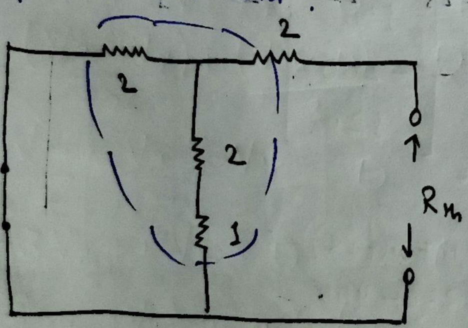
(II) All voltage sources in the circuit should be ~~open~~ short-circuited.

(III) All current sources in the circuit should be open-circuited.

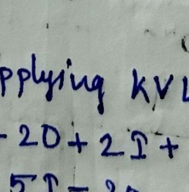




Step - I : Find R_{th} ?

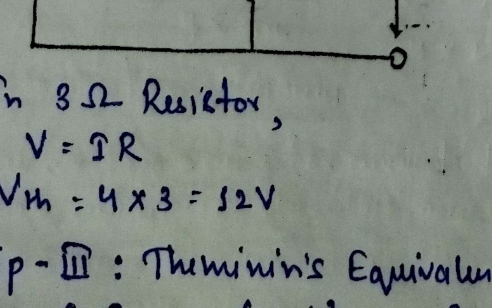


$$R_{th} = \left(\frac{2 \times 3}{2+3}\right) = \frac{6}{5} = 1.2\,\Omega$$



$$R_{th} = 2 + 1.2 = 3.2\,\Omega$$

Step - II : Calculate V_{th} ?



Applying KVL in loop,

$$-20 + 2I + 2I + I = 0$$
$$5I - 20 = 0$$
$$5I = 20$$
$$I = \frac{20}{5} = 4\,A$$

In $3\,\Omega$ Resistor,

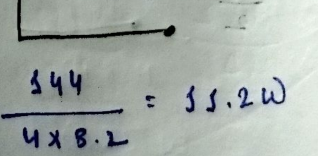
$V = IR$

$V_{th} = 4 \times 3 = 12V$

Step - III : Thevinin's Equivalent eqn

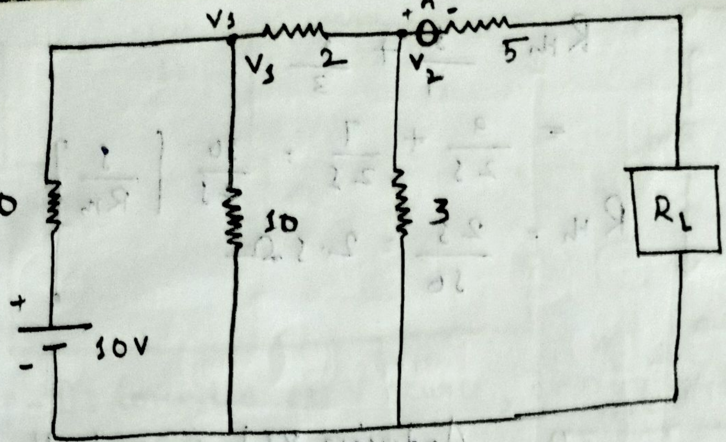
$$\left[P_{max} = \frac{(V_{th})^2}{4 \times R_{th}} \right]$$

↑ Max power transferred to circuit



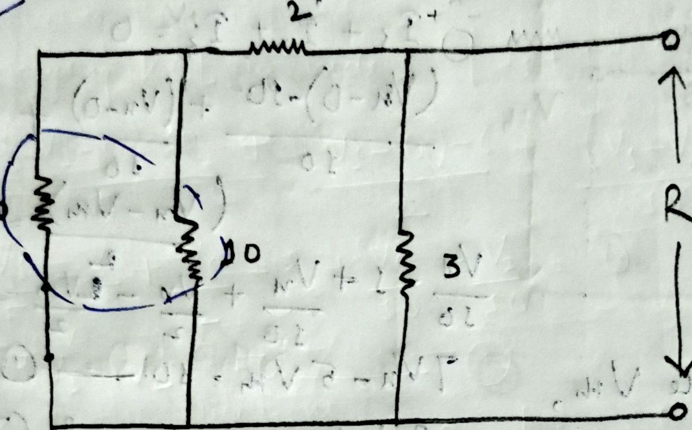
$$P_{max} = \frac{144}{4 \times 3.2} = 11.2\,W$$

9)

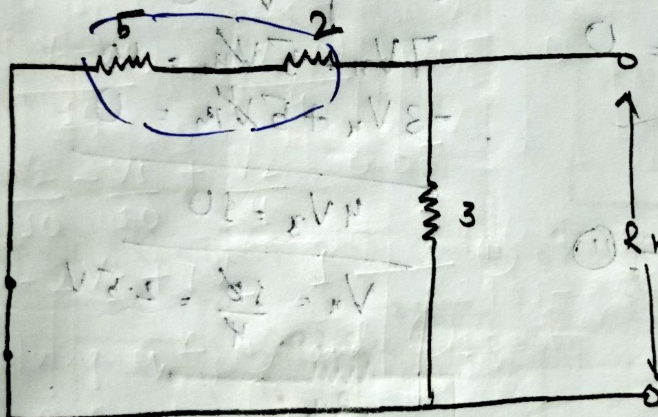


Rth

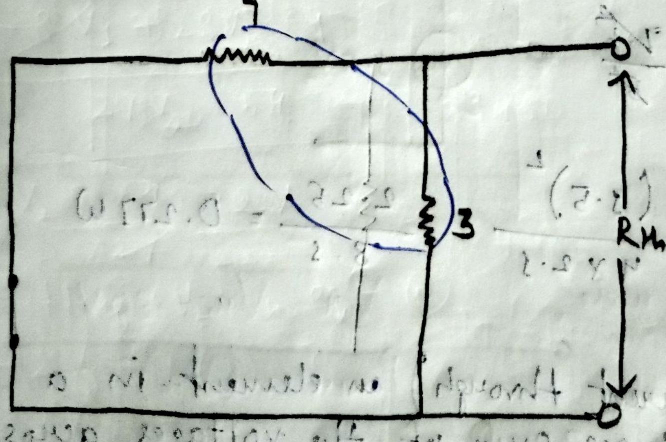
1



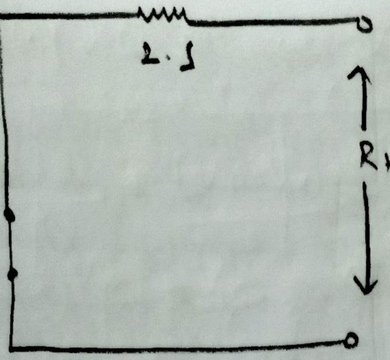
2



3



(4)

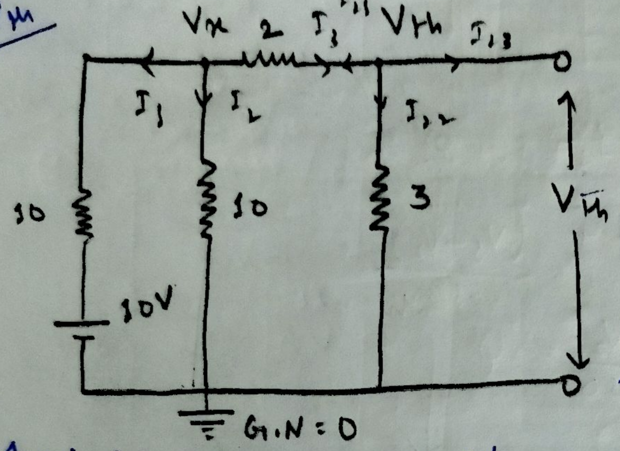


$$R_{th} = \frac{1}{7} + \frac{1}{3}$$

$$= \frac{3}{21} + \frac{7}{21} = \frac{10}{21} \left[\frac{1}{R_{th}}\right]$$

$$R_{th} = \frac{21}{10} = 2.1\,\Omega$$

V_{th}



Applying KCL in node V_x,

$$I_1 + I_2 + I_3 = 0$$

$$\frac{(V_x - 0) - 10}{10} + \frac{(V_x - 0)}{10} + \frac{(V_x - V_{th})}{2} = 0$$

$$\frac{V_x}{10} - 1 + \frac{V_x}{10} + \frac{V_x}{2} - \frac{V_{th}}{2} = 0$$

$$7V_x - 5V_{th} = 10 \quad \text{—— (i)}$$

Applying KCL in node V_{th},

$$I_{21} + I_{22} + I_{23} = 0$$

$$\frac{(V_{th} - V_x)}{2} + \frac{(V_{th} - 0)}{3} = 0$$

$$\frac{V_{th}}{2} - \frac{V_x}{2} + \frac{V_{th}}{3} = 0$$

$$-3V_x + 5V_{th} = 0 \quad \text{—— (ii)}$$

Solving eq^n (i) and (ii),

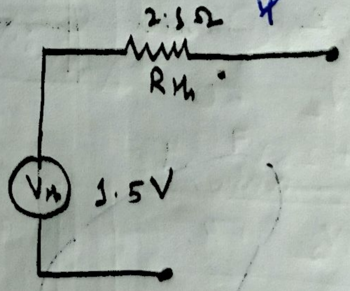
$$7V_x - \cancel{5V_{th}} = 10$$
$$-3V_x + \cancel{5V_{th}} = 0$$

$$4V_x = 10$$

$$V_x = \frac{10}{4} = 2.5\,V$$

Putting 'V_x' in eq^n (ii),

$$-3(2.5) + 5V_{th} = 0$$
$$-7.5 + 5V_{th} = 0$$
$$5V_{th} = 7.5 \Rightarrow V_{th} = \frac{7.5}{5}$$
$$V_{th} = 1.5\,V$$

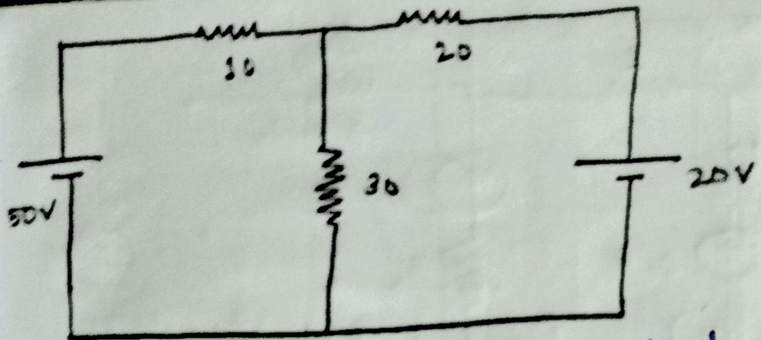


$$P_{max} = \frac{(V_{th})^2}{4 \times R_{th}} = \frac{(1.5)^2}{4 \times 2.1} = \frac{2.25}{8.1} = 0.277\,W$$

Superposition Theorem :-

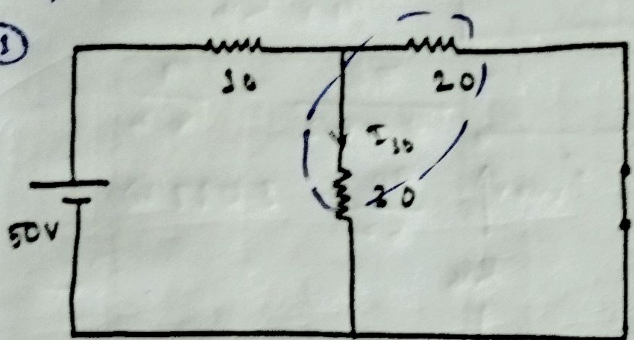
The voltage across (or current through) an element in a linear circuit is the algebraic sum of the voltages across (or currents through) that element due to each independent source acting alone.

Minimum two sources are required.



Step-I: Consider 50 V source, short-circuiting 20V source.

①



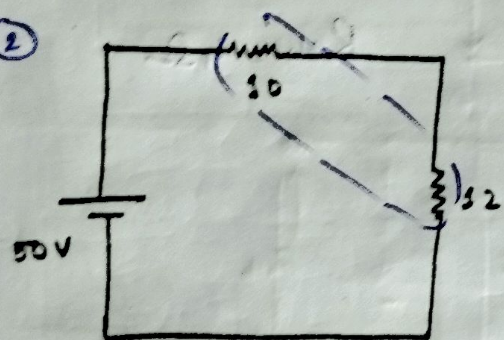
$V = 50V$; $R_{eq} = 22\Omega$

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

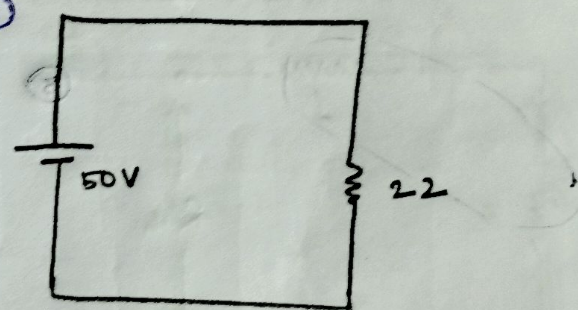
$I = \frac{50}{22} = 2.27\ A$

$I_{30} = 2.27 \times \frac{20}{50} = 0.908\ A$

②

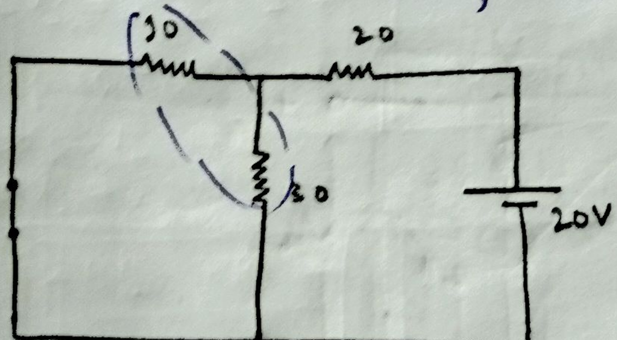


③



Step-II: Consider 20V source, short-circuiting 50V source.

①



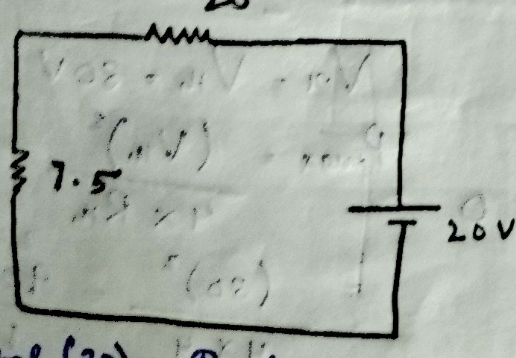
$V = 20V$; $R_{eq} = 27.5\ \Omega$

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

$I = \frac{20}{27.5} = 0.72\ A$

$I_{30} = 0.72 \times \frac{10}{40} = 0.18\ A$

②



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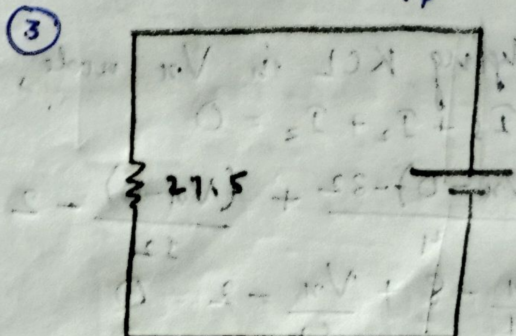


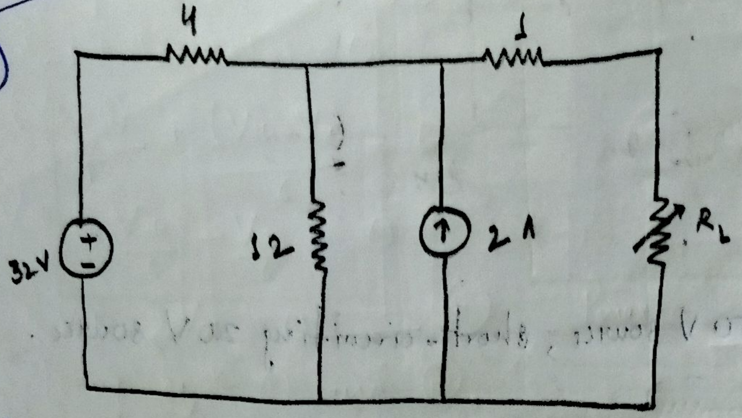
$I_{Total}(30) = I_{30}(50V) + I_{30}(20V)$

$= 0.908 + 0.18$

$= 1.088\ A$

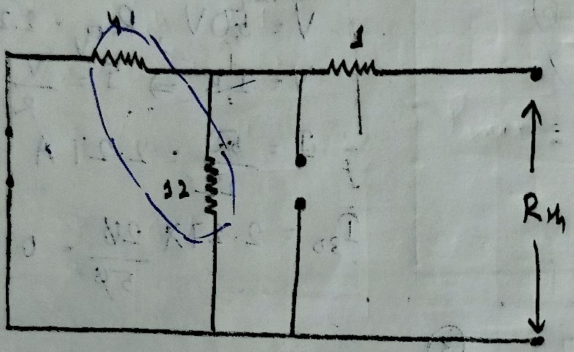
H.W (4)

Q)



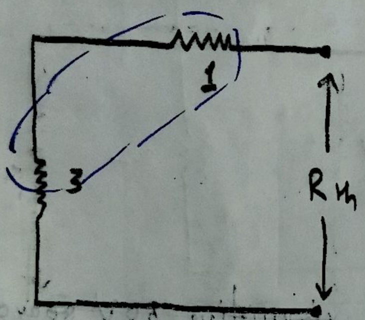
R_{th}

(1)

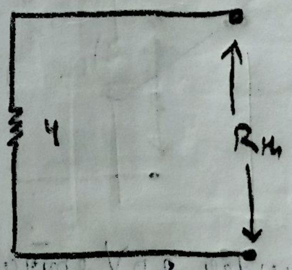


$R_{th} = 4\Omega$

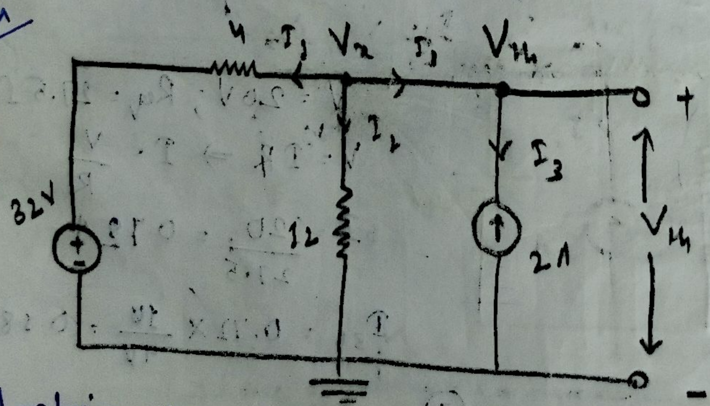
(2)



(3)



V_{th}



Applying KCL in V_x node,

$$I_1 + I_2 + I_3 = 0$$

$$\frac{(V_x - 0) - 32}{4} + \frac{(V_x - 0)}{12} - 2 = 0$$

$$\frac{V_x}{4} - 8 + \frac{V_x}{12} - 2 = 0$$

$$\frac{4V_x}{12} = 10 \Rightarrow 4V_x = 120$$

$$V_x = \frac{\cancel{120}}{\cancel{4}} = 30V$$

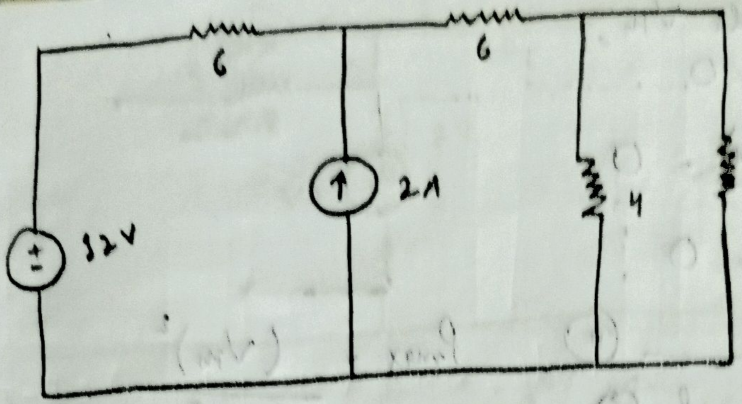
$$V_x = V_{th} = 30V$$

$$P_{max} = \frac{(V_{th})^2}{4 \times R_{th}}$$

$$= \frac{(30)^2}{4 \times 4} = \frac{\cancel{900}^{225}}{\cancel{16}_{4}}$$

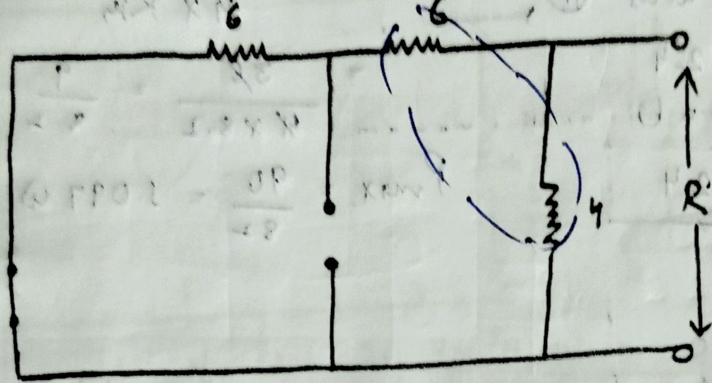
$$= 56.25 W$$

Q)



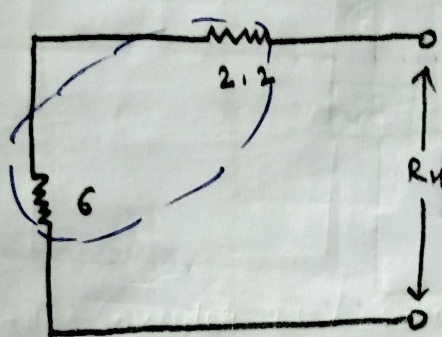
R_{th}

①

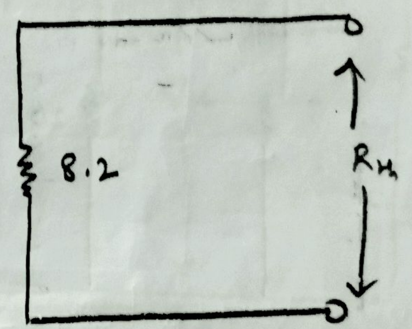


$R_{th} = 8.2\,\Omega$

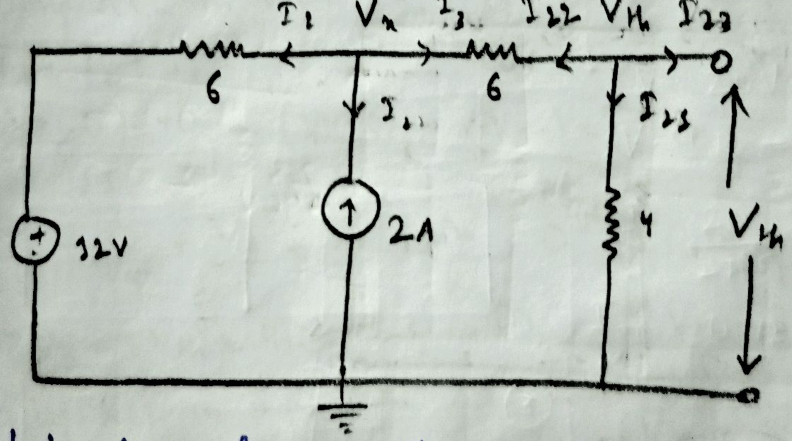
②



③



V_{th}



Applying KCL at node V_x,

$$I_1 + I_2 + I_3 = 0$$

$$\frac{(V_x - 0) - 12}{6} - 2 + \frac{(V_x - V_{th})}{6} = 0$$

$$\frac{V_x}{6} - 2 - 2 + \frac{V_x}{6} - \frac{V_{th}}{6} = 0$$

$$2V_x - V_{th} = 24 \quad \text{——} \quad ①$$

Applying KCL at node V_{th},

$I_{25} + I_{22} + I_{23} = 0$

$\frac{(V_{th} - 0)}{4} + \frac{(V_{th} - V_x)}{6} = 0$

$\frac{V_{th}}{4} + \frac{V_{th}}{6} - \frac{V_x}{6} = 0$

$5V_{th} - 2V_x = 0$ ——— (ii)

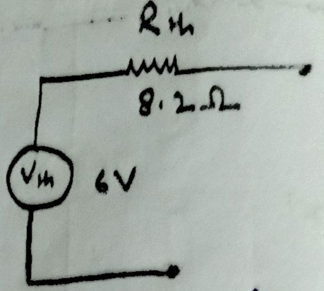
Solving eq^n (i) and (ii),

$2V_x - V_{th} = 24$

$-2V_x + 5V_{th} = 0$

$4V_{th} = 24$

$V_{th} = \frac{24}{4} = 6V$

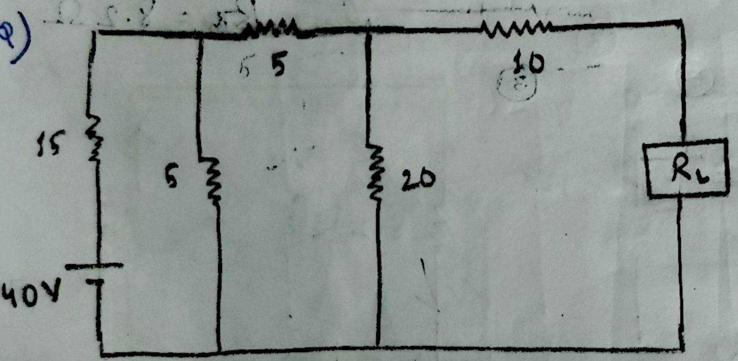


$P_{max} = \frac{(V_{th})^2}{4 \times R_{th}}$

$= \frac{36}{4 \times 8.2} = \frac{9}{8.2}$

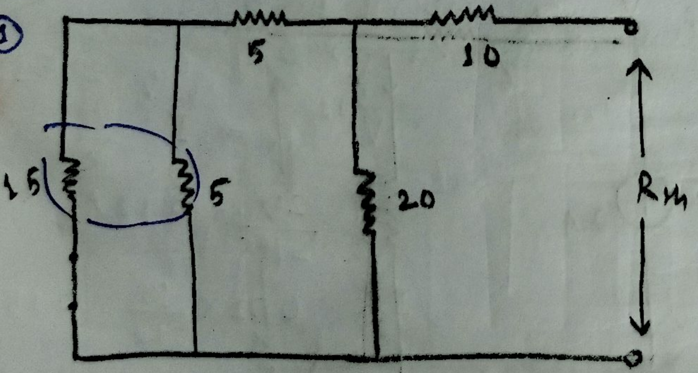
$\therefore P_{max} = \frac{90}{82} = 1.097\ W$

Q)

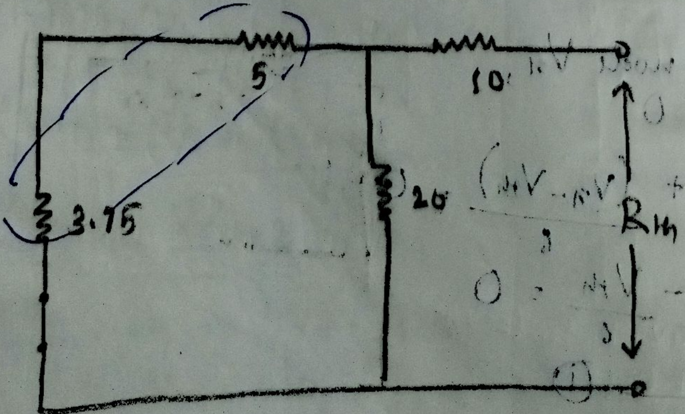


Rth

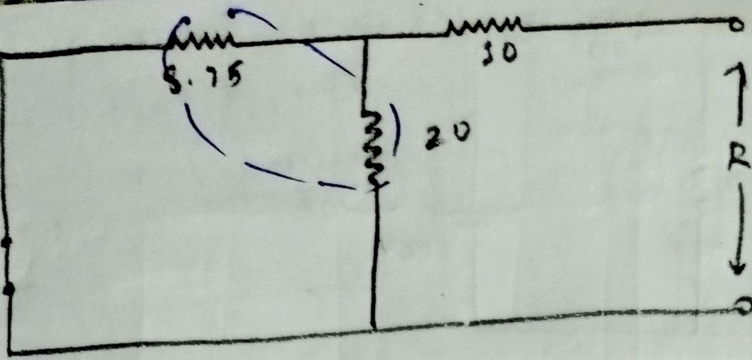
(1)



(2)

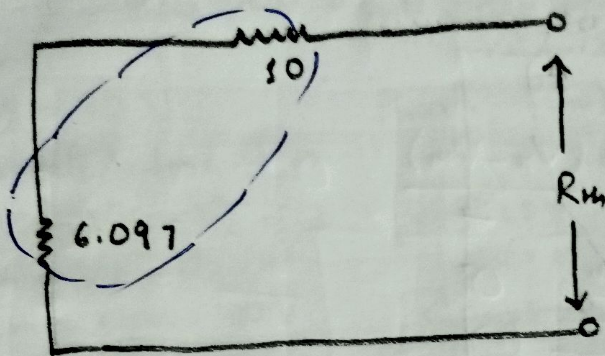


③

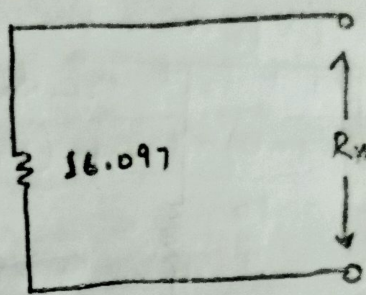


$R_{th} = 16.097\,\Omega$

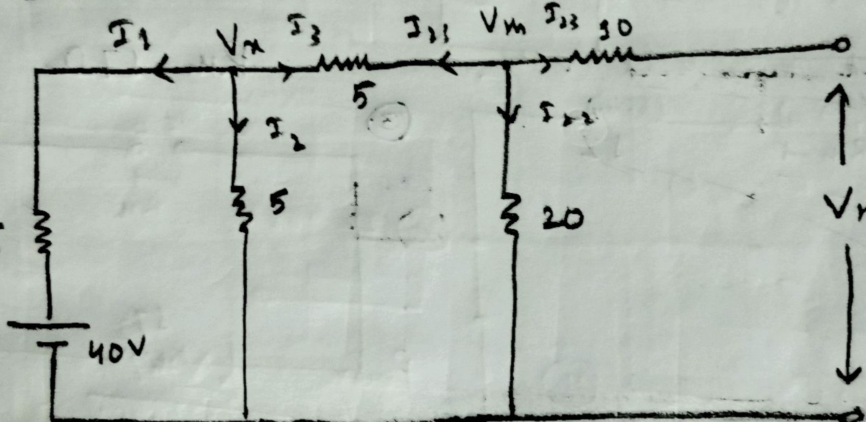
④



⑤



$\underline{V_{th}}$



Applying KCL in node V_x,

$$I_1 + I_2 + I_3 = 0$$

$$\frac{(V_x - 0) - 40}{15} + \frac{(V_x - 0)}{5} + \frac{(V_x - V_{th})}{5} = 0$$

$$\frac{V_x}{15} - \frac{40}{15} + \frac{V_x}{5} + \frac{V_x}{5} - \frac{V_{th}}{5} = 0$$

$$7V_x - 3V_{th} = 40 \quad \text{——— (I)}$$

Applying KCL in node V_{th},

$$I_{21} + I_{22} + I_{23} = 0$$

$$\frac{(V_{th} - V_x)}{5} + \frac{(V_{th} - 0)}{20} = 0$$

$$\frac{V_{th}}{5} - \frac{V_x}{5} + \frac{V_{th}}{20} = 0$$

$$V_{th} - V_x = 0$$

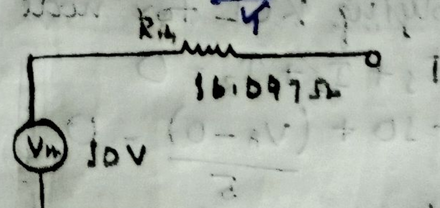
$$V_{th} = V_x \quad \text{——— (II)}$$

Putting eqⁿ (II) in (I),

$$7V_{th} - 3V_{th} = 40$$

$$4V_{th} = 40$$

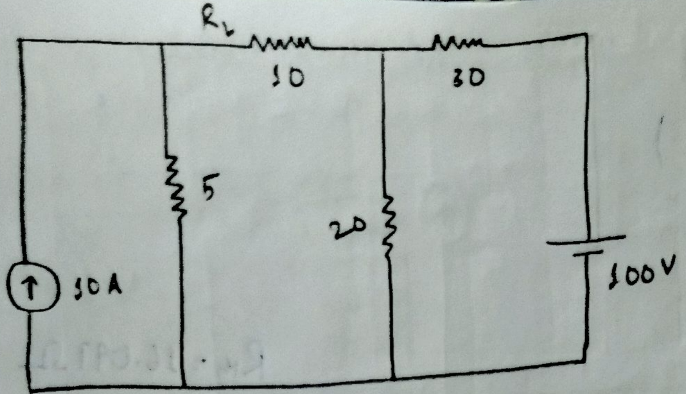
$$V_{th} = \frac{40}{4} = 10\,V$$



$$P_{max} = \frac{(V_{th})^2}{4 \times R_{th}} = \frac{100}{4 \times 16.097}$$

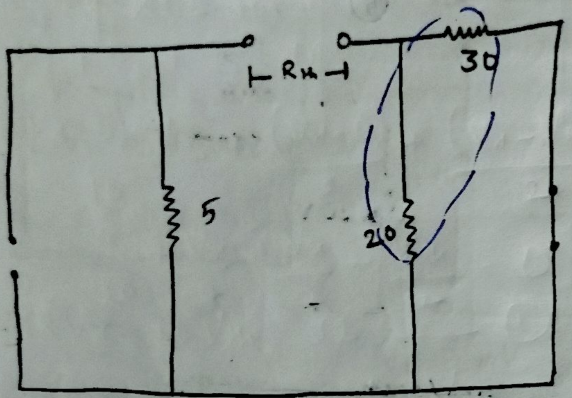
$$P_{max} = 1.553\,W$$

9)

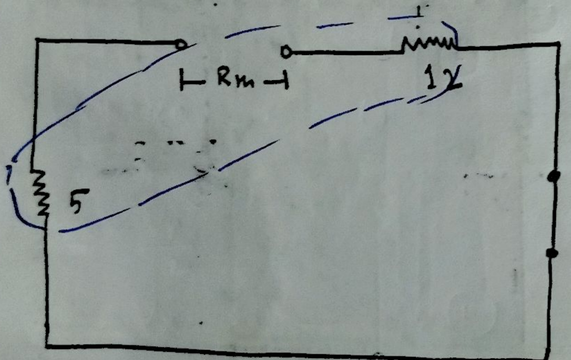


R_{th}

(1)

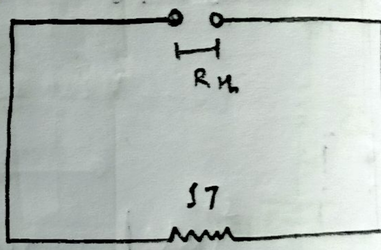


(2)

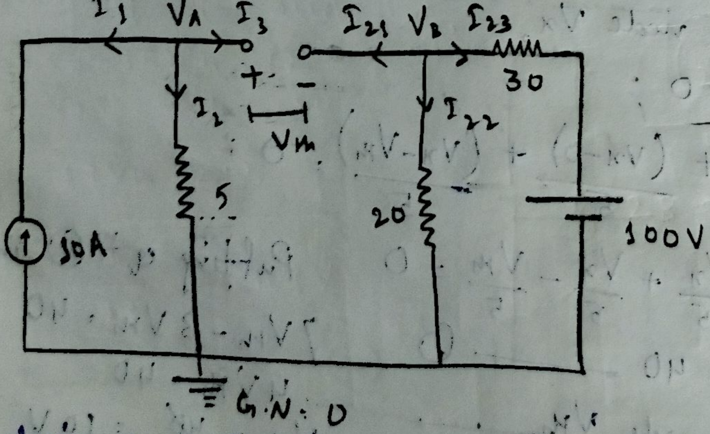


$R_{th} = 17\Omega$

(3)



V_{th}



Applying KCL for node V_A,

$$I_1 + I_2 + I_3 = 0$$

$$-10 + \frac{(V_A - 0)}{5} = 0$$

$$\frac{V_A}{5} = 10 \Rightarrow V_A = 50V$$

Applying KCL for node V_B,

$$I_{2\Omega} + I_{3\Omega} + I_{3\Omega} = 0$$

$$\frac{(V_B - 0)}{20} + \frac{(V_B - 0) - 100}{30} = 0$$

$$\frac{V_B}{20} + \frac{V_B}{30} - \frac{100}{30} = 0$$

$$\frac{5V_B}{60} = \frac{100}{30} \Rightarrow V_B = \frac{100}{30} \times \frac{60}{5}$$

$V_B = 40\,V$

V_{th} calculation :-

$$V_A - V_{th} - V_B = 0$$

$$V_{th} = V_A - V_B$$

$$V_{th} = 50V - 40V$$

$$V_{th} = 10V$$

V_{th} calculation :- (Second node V_B)

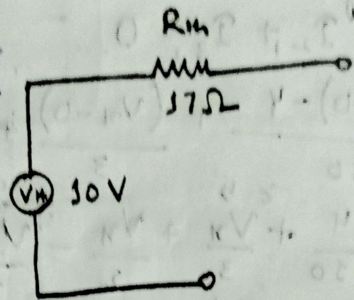
$$V_B + V_{th} - V_A = 0$$

$$V_{th} = V_A - V_B$$

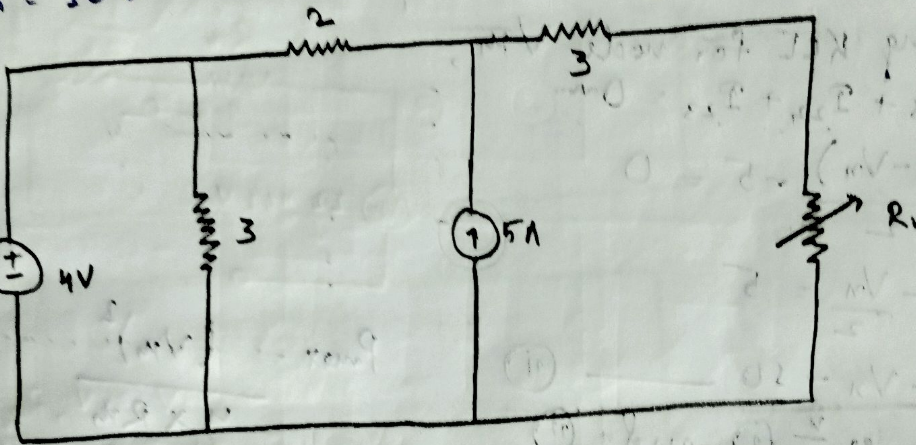
$$V_{th} = 50V - 40V$$

$$V_{th} = 10V$$

$$P_{max} = \frac{(V_{th})^2}{4 \times R_{th}} = \frac{100}{4 \times 17} = 1.47\,W$$

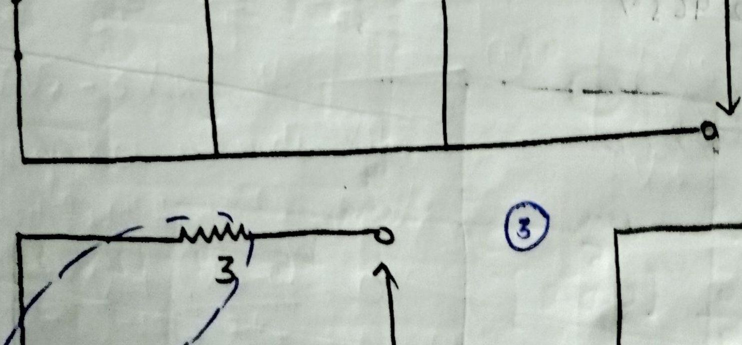


Q)



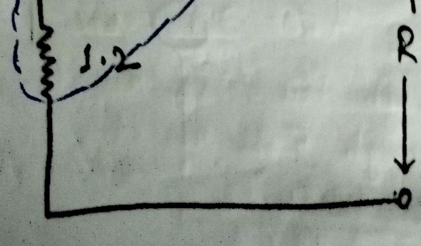
R_{th}

①

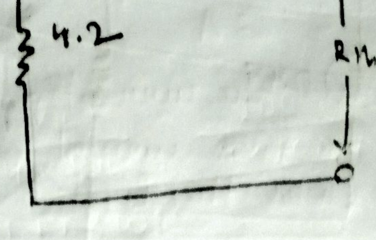


$R_{th} = 4.2\,\Omega$

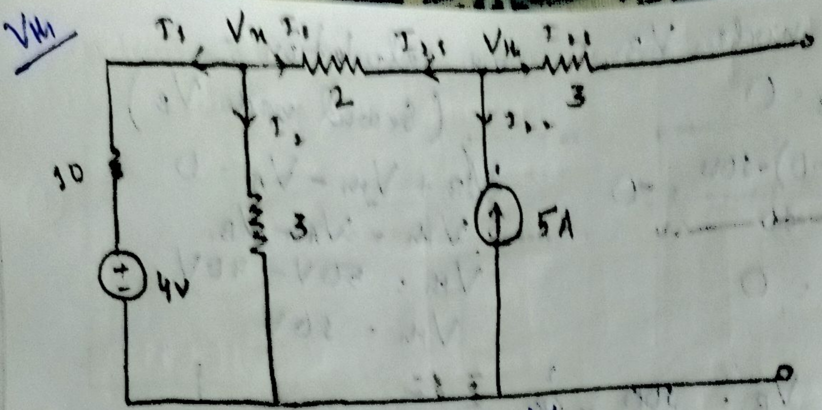
②



③



V_{th}



Applying KCL for node V_x,

$$I_1 + I_2 + I_3 = 0$$

$$\frac{(V_x-0)-4}{10} + \frac{(V_x-0)}{3} + \frac{(V_x-V_{th})}{2} = 0$$

$$\frac{V_x}{10} - \frac{4}{10} + \frac{V_x}{3} + \frac{V_x}{2} - \frac{V_{th}}{2} = 0$$

$$28V_x - 15V_{th} = 12 \quad \text{—— (i)}$$

Applying KCL for node V_{th},

$$I_{21} + I_{22} + I_{23} = 0$$

$$\frac{(V_{th}-V_x)}{2} - 5 = 0$$

$$\frac{V_{th}}{2} - \frac{V_x}{2} = 5$$

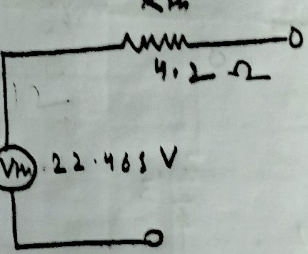
$$V_{th} - V_x = 10 \quad \text{—— (ii)}$$

Solving eq^n (i) and (ii),

$$28V_x - 15V_{th} = 12$$
$$-28V_x + 28V_{th} = 280$$

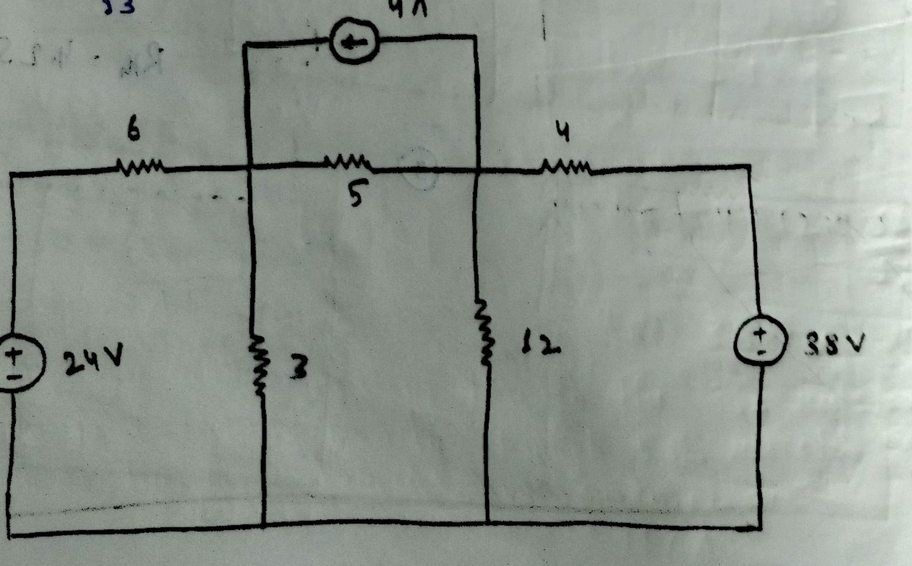
$$13V_{th} = 292$$

$$V_{th} = \frac{292}{13} = 22.461\text{ V}$$

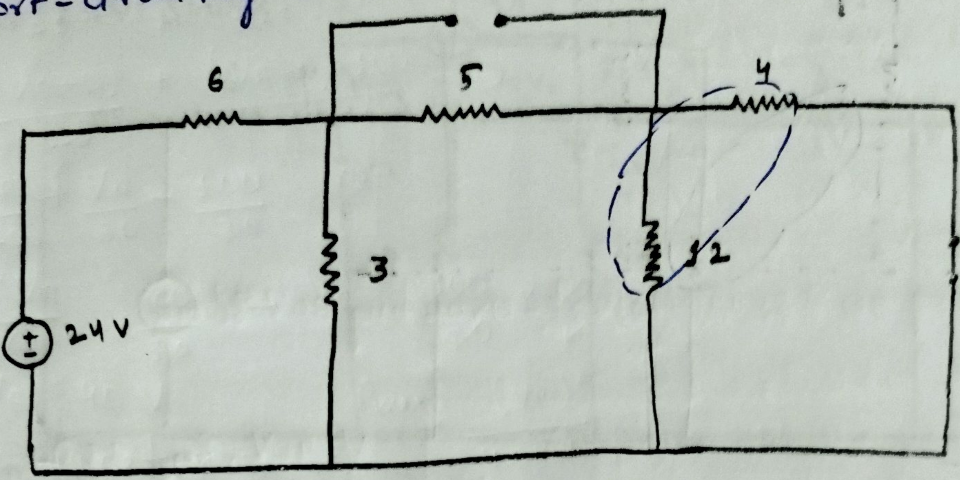


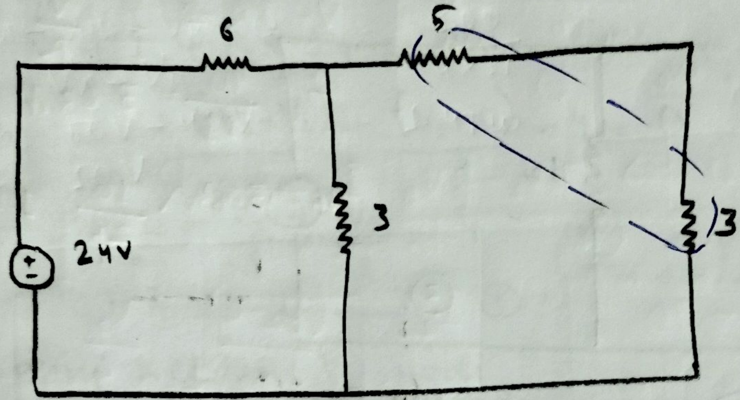
$$P_{max} = \frac{(V_{th})^2}{4 \times R_{th}} = \frac{(22.461)^2}{4 \times 4.2} = 28.842\text{ W}$$

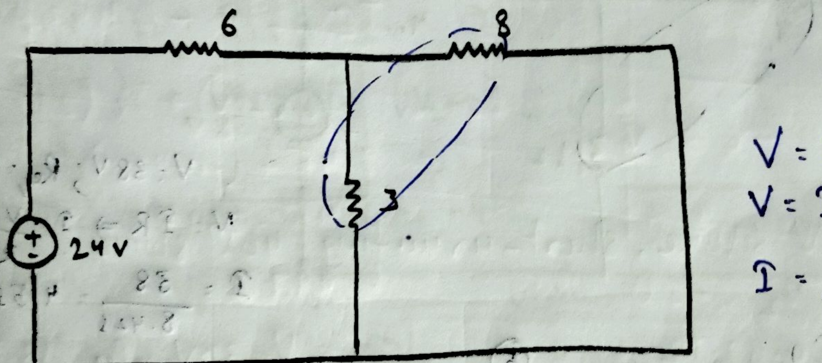
9)



Considering 24V source, open-circuiting 4A source and short-circuiting 88V.

① 

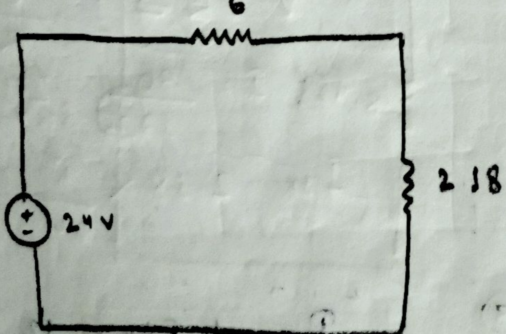
② 

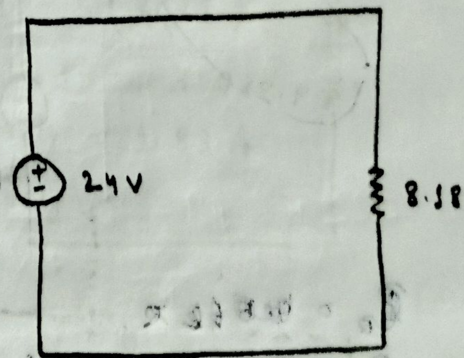
③ 

$V = 24V$; $R_{eq} = 8.18\,\Omega$

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

$I = \frac{24}{8.18} = 2.93\,A$

④ 

⑤ 

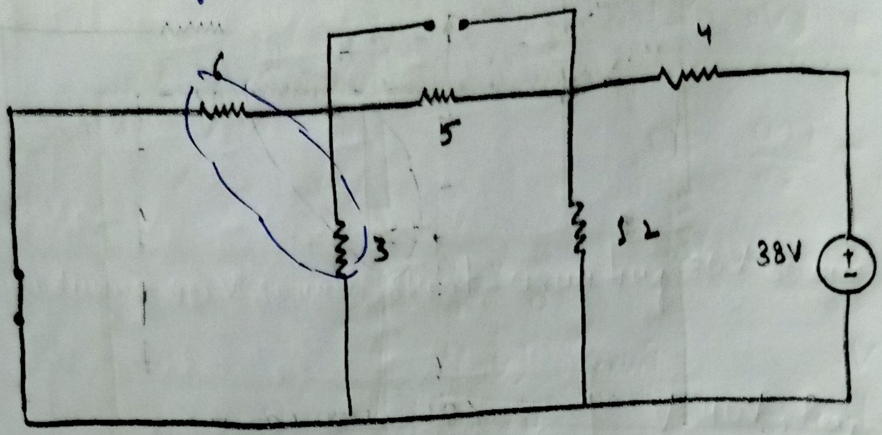
$I_3 = 2.93 * \frac{5}{8}$ [Current-Division Rule]

$I_3 = 1.83125\,A$

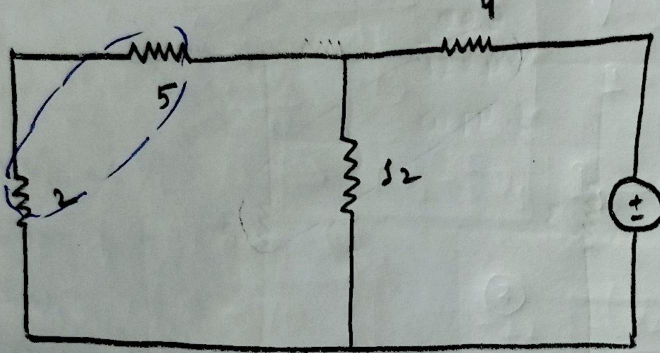
[I_3 = Current flowing through $3\,\Omega$ resistor].

Considering 38 V source, open-circuiting 4 A source and short circuiting 24 V source.

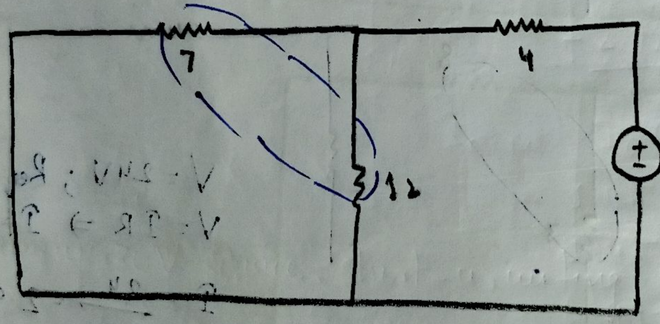
(1)



(2)



(3)

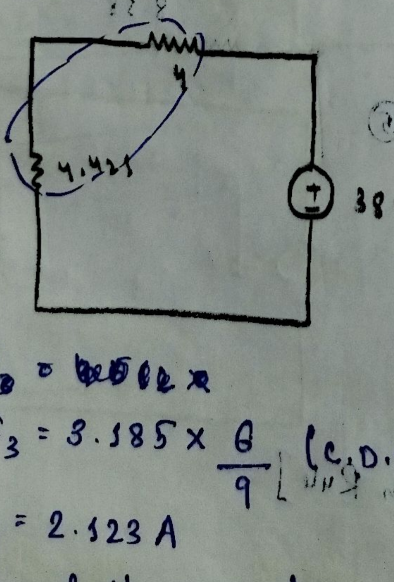


$V = 38\,V$; $R_{eq} = 8.421\,\Omega$

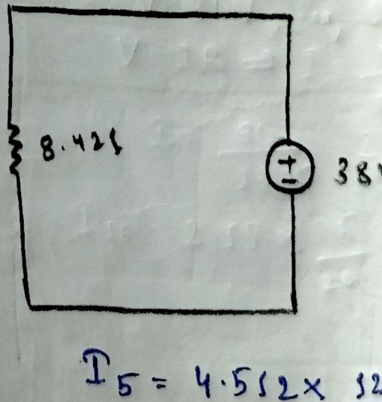
$V = IR \Rightarrow I = \frac{V}{R}$

$I = \frac{38}{8.421} = 4.512\,A$

(4)



(5)



$I_3 = 3.185 \times \frac{6}{9}$ [C.D.R]

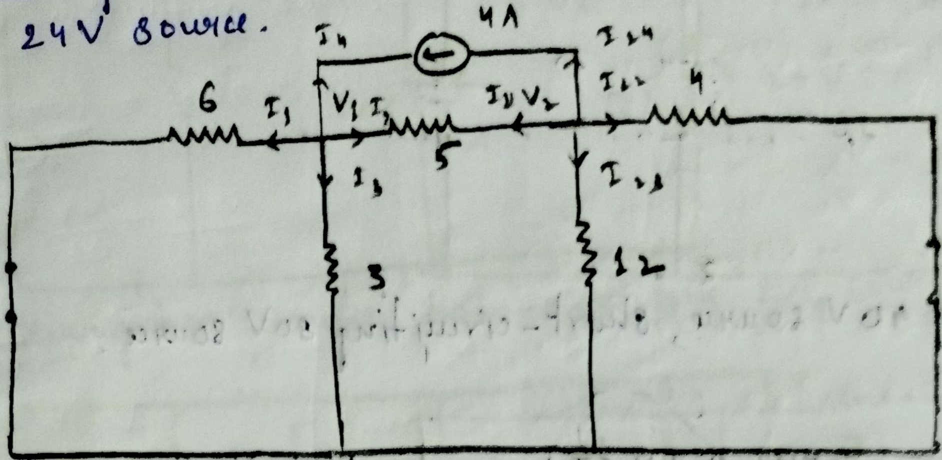
$I_3 = 2.123$ A

$I_5 = 4.512 \times \frac{12}{17}$

$I_5 = 3.185$ A

* Found the current passing through the 3 Ω resistor. Had to find current passing through 5 Ω resistor because that was the first branch from source.

Considering the 4A source and short-circuiting the 38V and 24V source.



Applying KCL in V_1 node,

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

$$\frac{(V_1-0)}{6} + \frac{(V_1-V_2)}{5} + \frac{(V_1-0)}{3} - 4 = 0$$

$$\frac{V_1}{6} + \frac{V_1}{5} - \frac{V_2}{5} + \frac{V_1}{3} = 4$$

$$7V_1 - 2V_2 = 40 \quad \text{——— (i)}$$

Applying KCL in V_2 node,

$$I_{21} + I_{22} + I_{23} + I_{24} = 0$$

$$\frac{(V_2-V_1)}{5} + \frac{(V_2-0)}{4} + \frac{(V_2-0)}{12} + 4 = 0$$

$$\frac{V_2}{5} - \frac{V_1}{5} + \frac{V_2}{4} + \frac{V_2}{12} = -4$$

$$8V_2 - 3V_1 = -60 \quad \text{——— (ii)}$$

Solving eq^n (i) and (ii),

$$28V_1 - \cancel{8V_2} = 160$$
$$-3V_1 + \cancel{8V_2} = -60$$

$$25V_1 = 100$$

$$V_1 = \frac{100}{25} = 4V$$

Now,

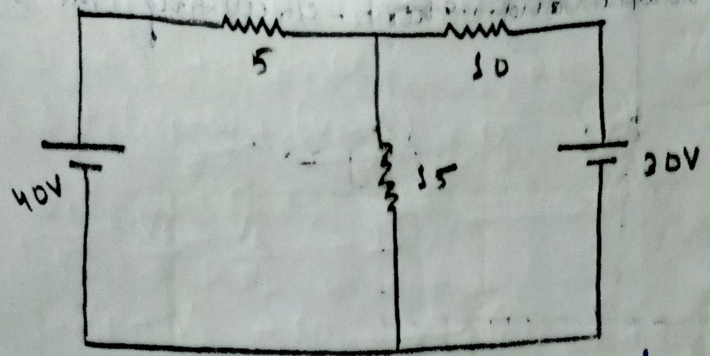
$$I_3 = \frac{(V_1-0)}{3} = \frac{V_1}{3}$$

$$I_3 = \frac{4}{3} = 1.33\ A$$

Thus,

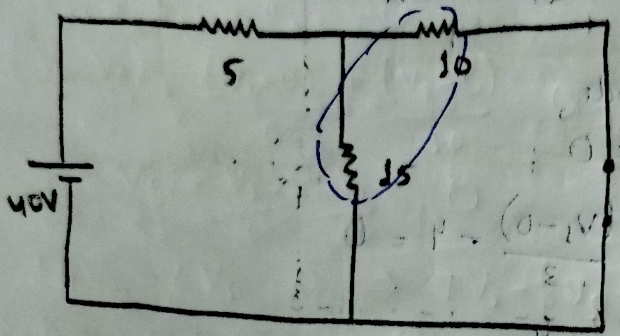
$$I_3\,(\text{Total}) = I_3\,(24V) + I_3\,(38V) + I_3\,(4A)$$
$$= 1.83125 + 2.123 + 1.33$$
$$= 5.28425\ A$$

Q)



Considering 40V source, short-circuiting 30V source.

①



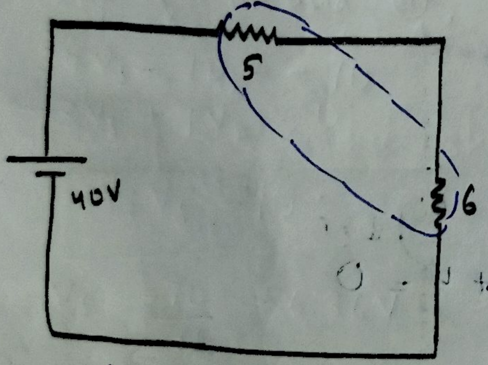
$V = 40V$; $R_{eq} = 11\,\Omega$

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

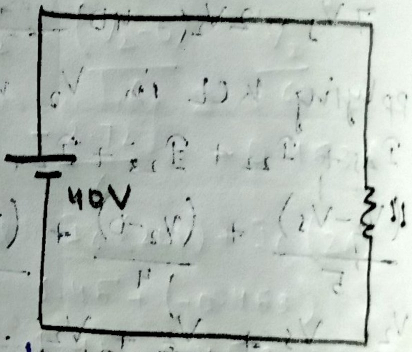
$I = \frac{40}{11} = 3.63\,A$

$I_{15} = 3.63 \times \frac{10}{25} = 1.452$

②

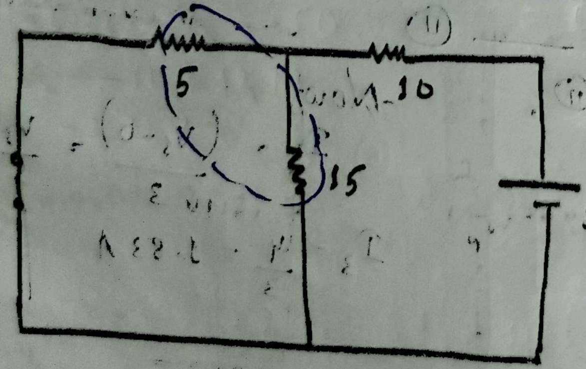


③



Considering 30V source, short-circuiting 40V source.

①



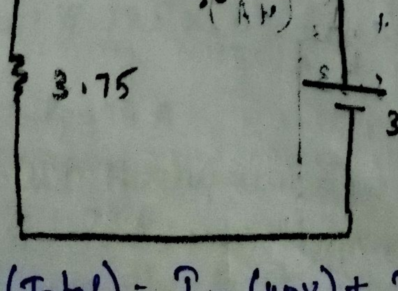
$V = 30V$; $R_{eq} = 13.75\,\Omega$

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

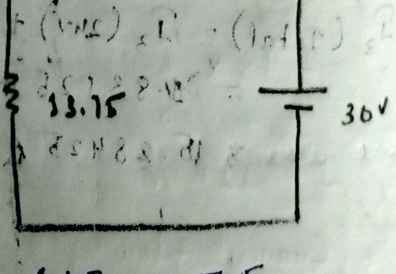
$I = \frac{30}{13.75} = 2.18\,A$

$I_{15} = 2.18 \times \frac{5}{20} = 0.545$

②



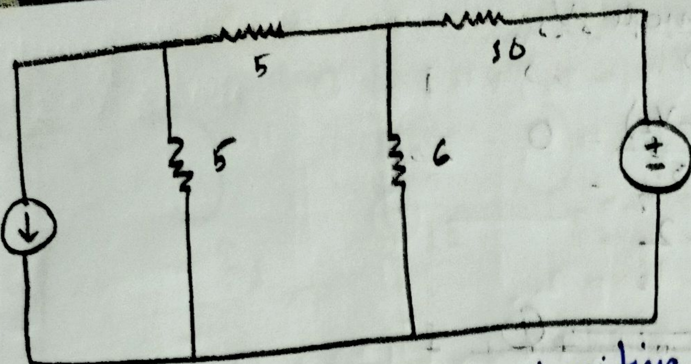
③



$I_{15}\,(\text{Total}) = I_{15}\,(40V) + I_{15}\,(30V) = 1.452 + 0.545$

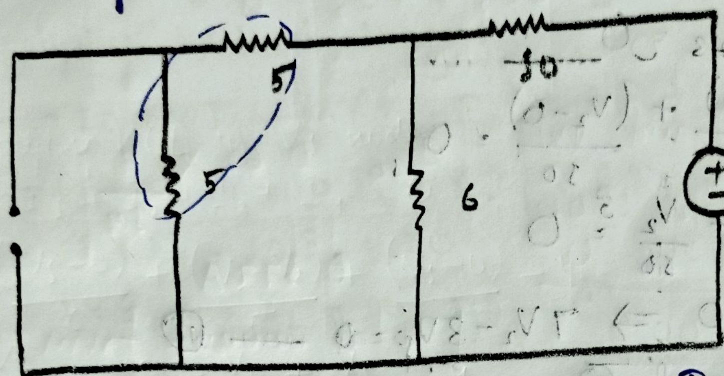
$= 1.997\,A$

9)

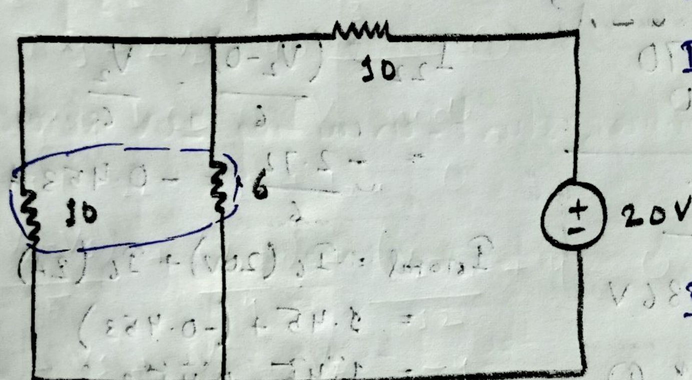


Considering 20V source, open-circuiting 2A source.

①



②



$I_i = 1.45 \times \frac{5}{11}$

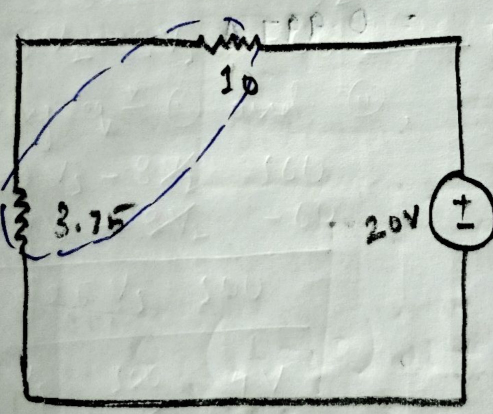
$I_i = 0.132\ A$

$V = 20V$; $R_{eq} = 13.75\ \Omega$

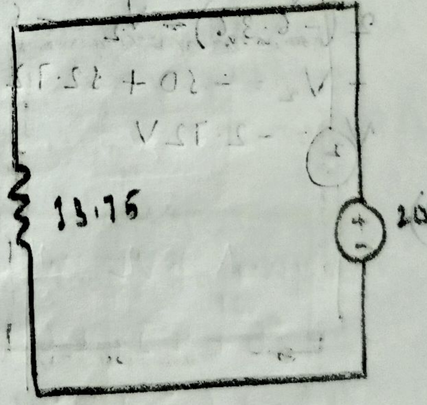
$V = IR \Rightarrow I = \frac{V}{R}$

$I = \frac{20}{13.75} = 1.45\ A$

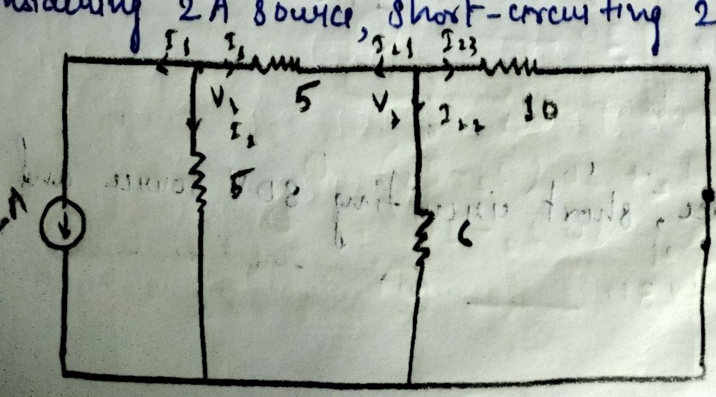
③



④



Considering 2A source, short-circuiting 20V source.



Applying KCL for node V_1,

$$I_1 + I_2 + I_3 = 0$$

$$2 + \frac{(V_1 - 0)}{5} + \frac{(V_1 - V_2)}{5} = 0$$

$$\frac{V_1}{5} + \frac{V_1}{5} - \frac{V_2}{5} = -2$$

$$2V_1 - V_2 = -10 \quad \text{——— (i)}$$

Applying KCL for node V_2,

$$I_{21} + I_{22} + I_{23} = 0$$

$$\frac{(V_2 - V_1)}{5} + \frac{(V_2 - 0)}{6} + \frac{(V_2 - 0)}{10} = 0$$

$$\frac{V_2}{5} - \frac{V_1}{5} + \frac{V_2}{6} + \frac{V_2}{10} = 0$$

$$14V_2 - 6V_1 = 0 \Rightarrow 7V_2 - 3V_1 = 0 \quad \text{——— (ii)}$$

Solving eq^n (i) and (ii),

$$14V_1 - 7V_2 = -70$$
$$-3V_1 + 7V_2 = 0$$

$$11V_1 = -70$$

$$\therefore V_1 = \frac{-70}{11} = -6.36\,V$$

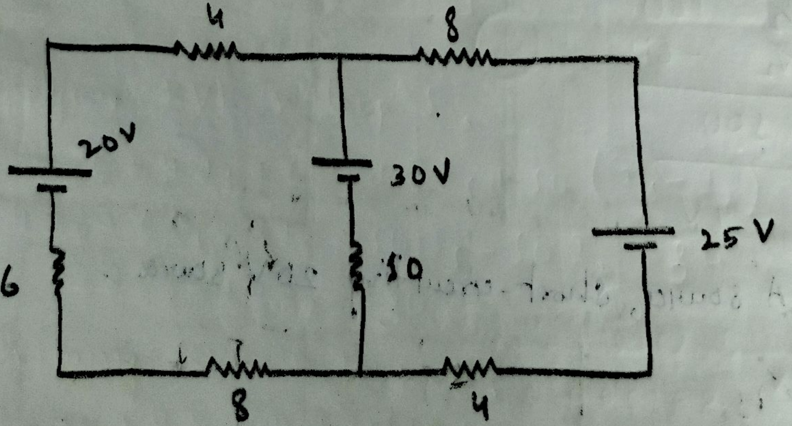
Putting 'V_1' in eq^n (i),

$$2(-6.36) - V_2 = -10$$
$$-V_2 = -10 + 12.72$$
$$V_2 = -2.72\,V$$

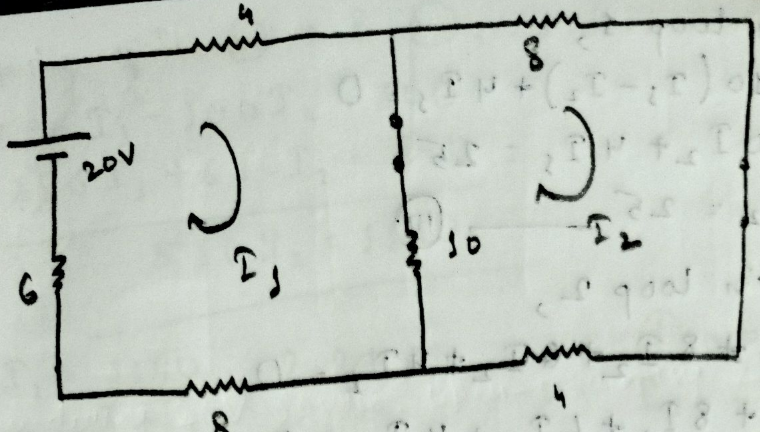
$$I_{22} = \frac{(V_2 - 0)}{6} = \frac{V_2}{6}$$
$$= \frac{-2.72}{6} = -0.453\,A$$

$$I_{TOTAL} = I_6(20V) + I_6(2A)$$
$$= 1.45 + (-0.453)$$
$$= 1.45 - 0.453$$
$$= 0.997\,A$$

9)



Considering 20V source, short circuiting 30V source and 25V source.



Applying KVL in loop 1,

$$-20 + 4I_1 + 10(I_1 - I_2) + 8I_1 + 6I_1 = 0$$

$$4I_1 + 10I_1 - 10I_2 + 8I_1 + 6I_1 = 20$$

$$28I_1 - 10I_2 = 20$$

$$14I_1 - 5I_2 = 10 \quad \text{—— (i)}$$

Applying KVL in loop 2,

$$-8I_2 + 4I_2 + 10(I_2 - I_1) = 0$$

$$-8I_2 + 4I_2 + 10I_2 - 10I_1 = 0$$

$$6I_2 - 10I_1 = 0 \quad \text{—— (ii)}$$

Solving eqn (i) and (ii),

$$84I_1 - 30\cancel{I_2} = 60$$

$$-50I_1 + 30\cancel{I_2} = 0$$

$$34I_1 = 60$$

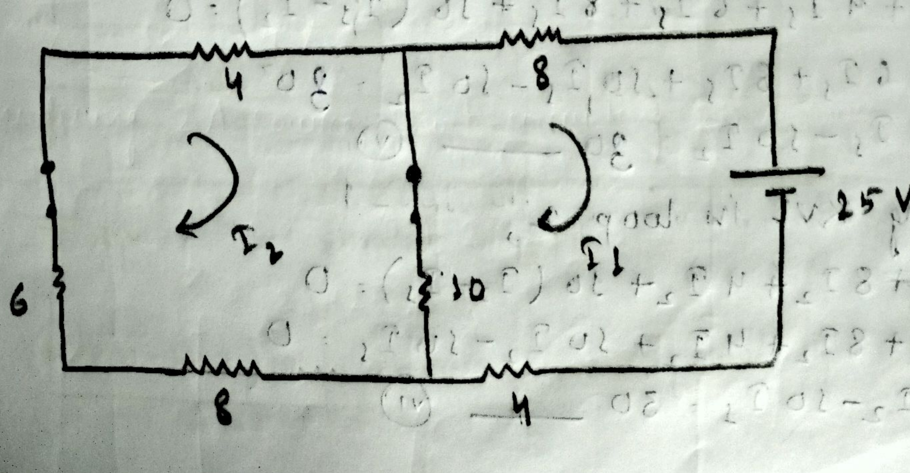
$$I_1 = \frac{60}{34} = 1.764 \text{ A}$$

$$I_{10} = 1.764 \times \frac{8}{18}$$

$$= 0.784 \text{ A}$$

I_1 = Total current from source of 20 V getting divided into 10 Ω and 8 Ω resistor.

Considering 25 V source, short circuiting 10V and 20 V source. [Again we've to take loops for KVL]



Applying KVL in loop 1,

$-25 + 8I_1 + 10(I_1 - I_2) + 4I_1 = 0$

$8I_1 + 10I_1 - 10I_2 + 4I_1 = 25$

$32I_1 - 10I_2 = 25$ —— (iii)

Applying KVL in loop 2,

$-10(I_2 - I_1) + 8I_2 + 6I_2 + 4I_2 = 0$

$-10I_2 + 10I_1 + 8I_2 + 6I_2 + 4I_2 = 0$

$12I_2 + 10I_1 = 0$ —— (iv)

Solving eq^n (iii) and (iv),

$384I_1 - 120I_2 = 300$

$100I_1 + 120I_2 = 0$

$484I_1 = 300$

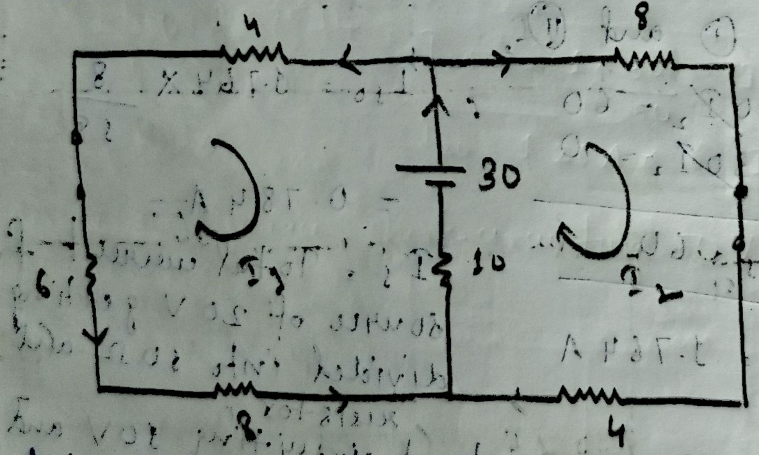
$I_1 = \frac{300}{484} = 0.62\,A$

$I_{10} = 0.62 \times \frac{4}{14}$

$= 0.177\,A$

[Total current from branching is I_1]

Considering 30V source, short-circuiting 20V source and 25V source.



Applying KVL in loop 1

$-30 + 4I_1 + 6I_1 + 8I_1 + 10(I_1 - I_2) = 0$

$4I_1 + 6I_1 + 8I_1 + 10I_1 - 10I_2 = 30$

$28I_1 - 10I_2 = 30$ —— (v)

Applying KVL in loop 2,

$-30 + 8I_2 + 4I_2 + 10(I_2 - I_1) = 0$

$-30 + 8I_2 + 4I_2 + 10I_2 - 10I_1 = 0$

$22I_2 - 10I_1 = 30$ —— (vi)

Solving eq^n (v) and (vi),

$$280 I_1 - 100 I_2 = 800$$
$$-280 I_1 + 616 I_2 = 840$$
$$516 I_2 = 1140$$

$$I_2 = \frac{1140}{516} = 2.21\ A$$

Putting 'I_2' in eq^n (i),

$$28 I_1 - 10(2.21) = 80$$
$$28 I_1 - 22.1 = 30$$
$$28 I_1 = 52.1$$
$$I_1 = \frac{52.1}{28} = 1.86\ A$$

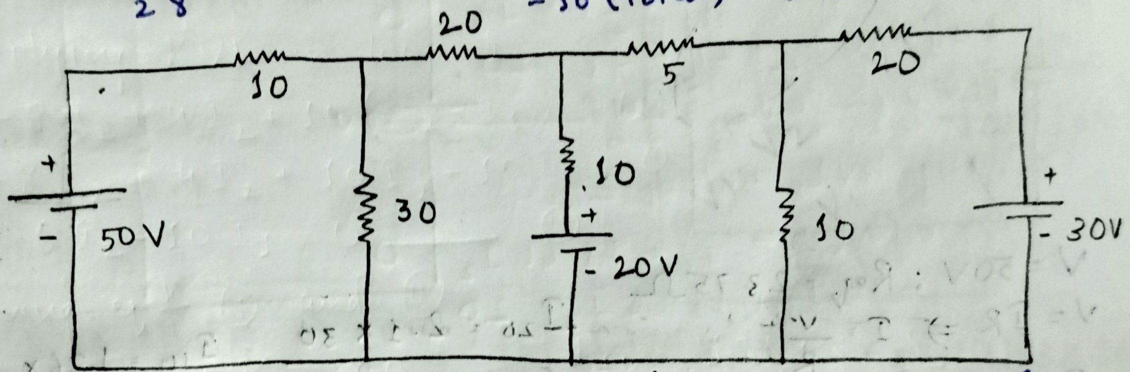
$$I_{10} = I_1 + I_2$$
$$I_{10} = 2.21 + 1.86$$
$$= 4.07\ A$$

$$I_{10}\ (\text{Total}) = I_{10}\ (20V) + I_{10}\ (25V) + I_{10}\ (30V)$$

$$I_{10}\ (\text{Total}) = 0.784 + 0.62 + 4.07$$

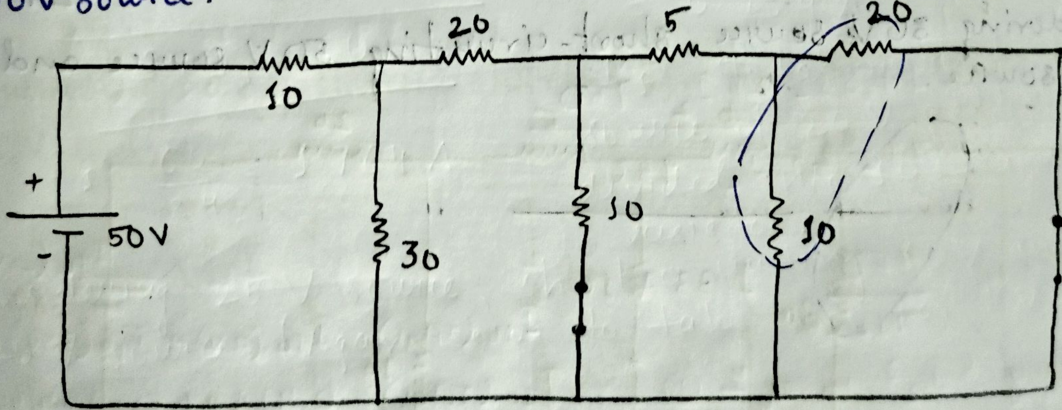
$$I_{10}\ (\text{Total}) = 5.474\ A$$

a)

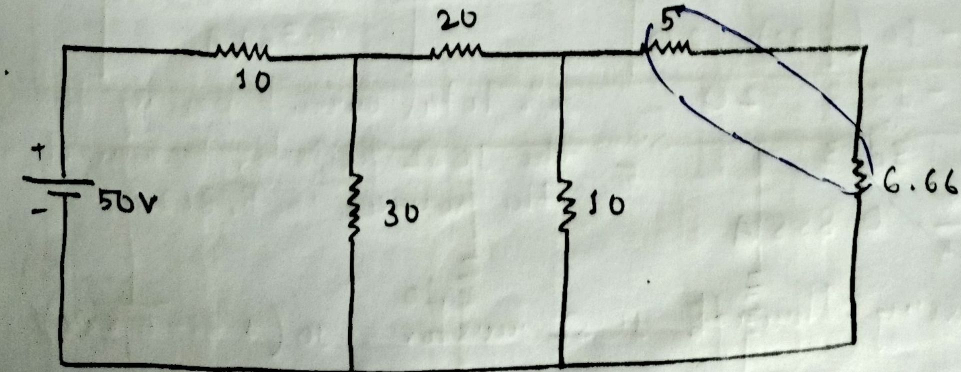


Considering 50V source, short-circuiting 20V source and 30V source.

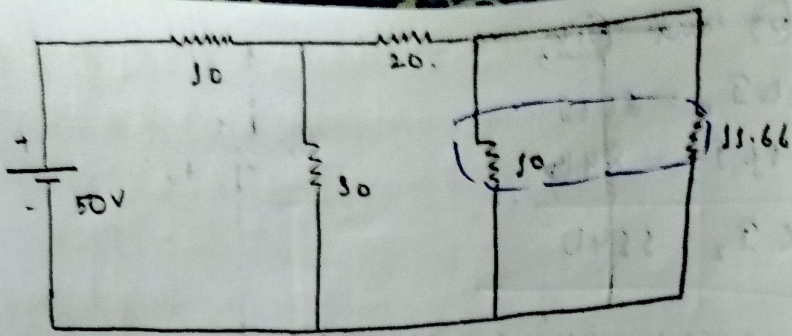
(1)



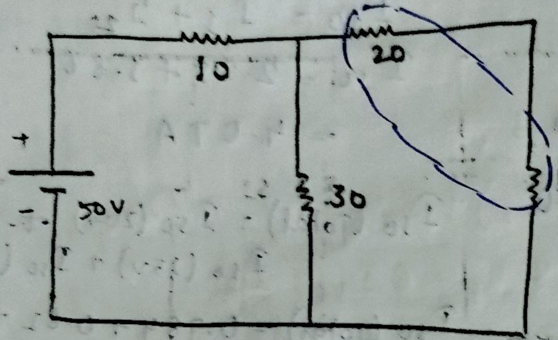
(2)



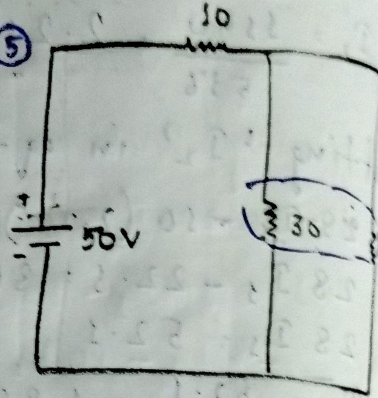
(3)



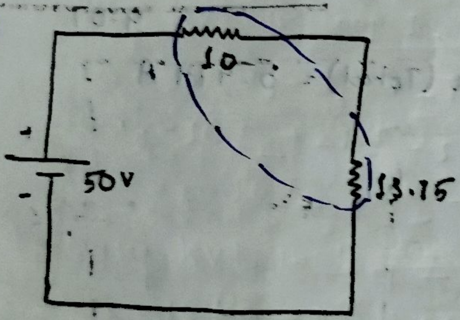
(4)



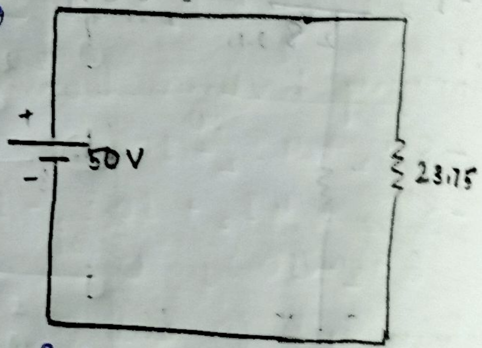
(5)



(6)



(7)



$V = 50V$; $R_{eq} = 23.75\,\Omega$

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

$I = \frac{50}{23.75} = 2.1\,A$

$I_{20} = 2.1 \times \frac{30}{50}$

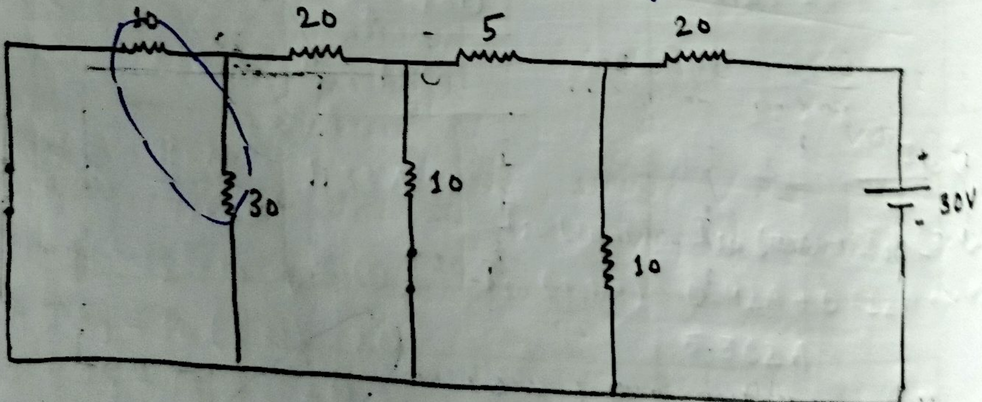
$I_{20} = 1.26\,A$

$I_{10} = 1.26 \times \frac{5}{15}$

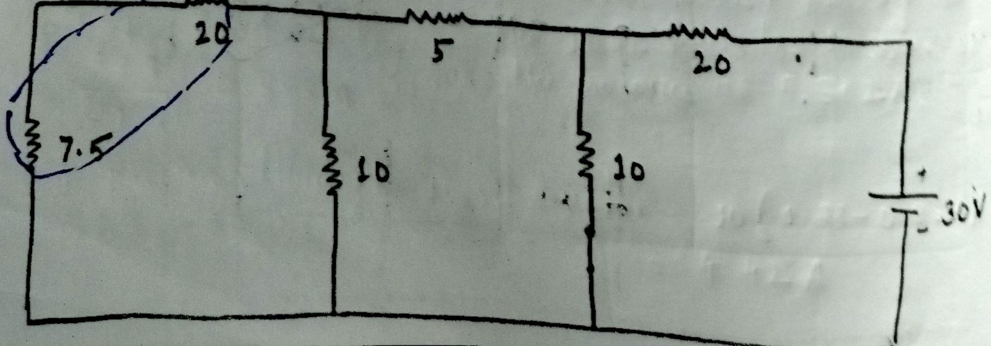
$I_{10} = 0.42\,A$

Considering 30V source, short-circuiting 50V source and 20V source.

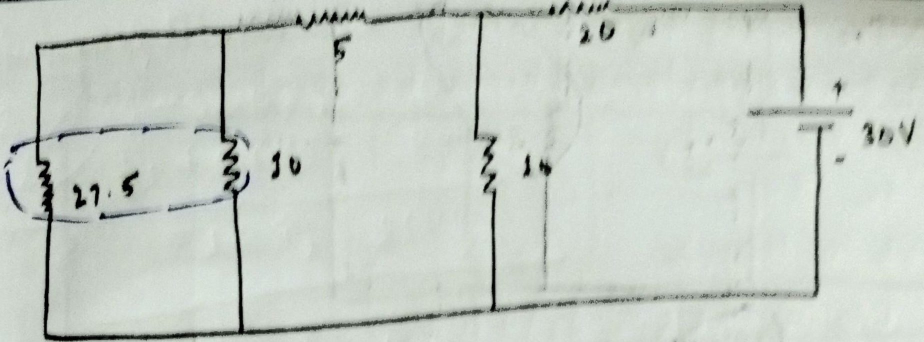
(1)



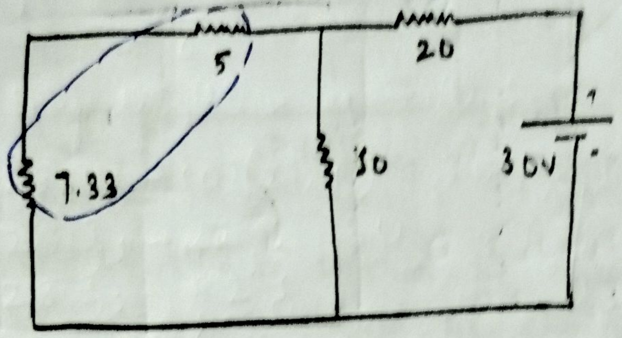
(2)



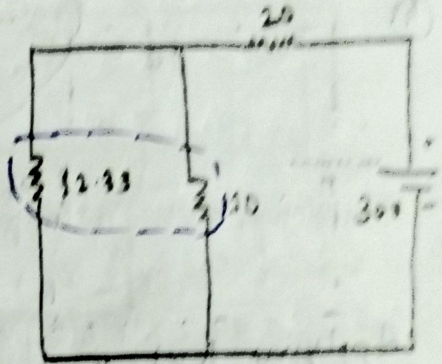
③



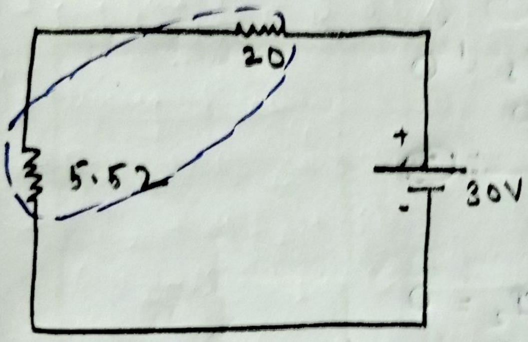
④



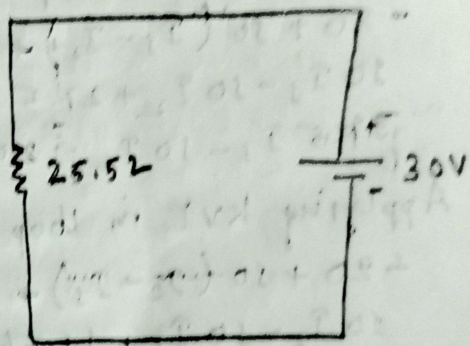
⑤



⑥



⑦



$V = 30V \; ; \; R_{eq} = 25.52\Omega$

$V = IR \rightarrow I = \frac{V}{R}$

$I = \frac{30}{25.52} = 1.175A$

$I_5 = 1.175 \times \frac{10}{15}$

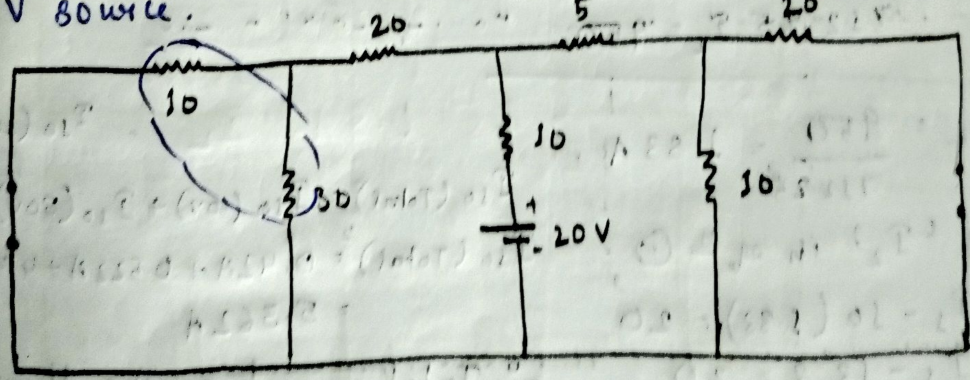
$I_5 = 0.783A$

$I_{10} = 0.783 \times \frac{20}{30}$

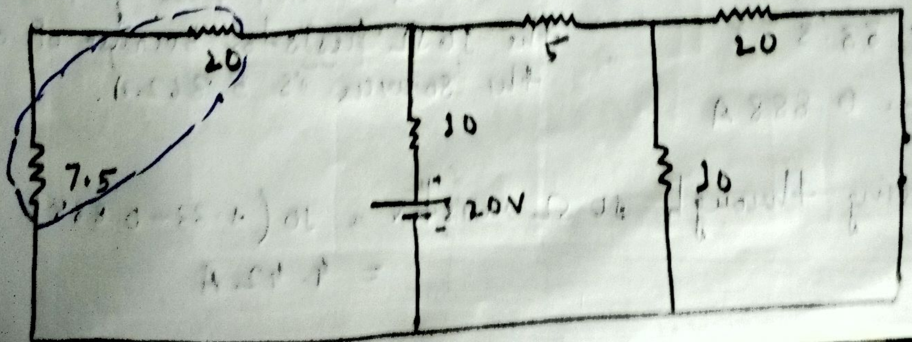
$I_{10} = 0.522A$

Considering 20V source, short-circuiting 50V source and 30V source.

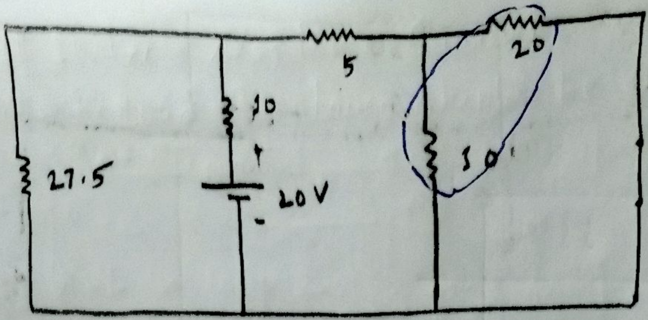
①



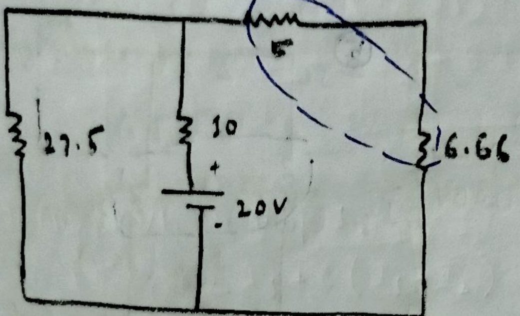
②



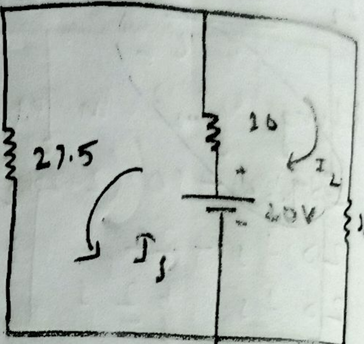
③



④



⑤



Applying KVL in loop 1,

$-20 + 10(I_1 - I_2) + 27.5\, I_1 = 0$

$10 I_1 - 10 I_2 + 27.5\, I_1 = 20$

$37.5\, I_1 - 10\, I_2 = 20$ ———— ①

Applying KVL in loop 2,

$-20 + 10(I_2 - I_1) + 11.66\, I_2 = 0$

$10 I_2 - 10 I_1 + 11.66\, I_2 = 20$

$-10 I_1 + 21.66\, I_2 = 20$ ———— ⑪

Solving eq$^{\underline{n}}$ ① and ⑪,

$\cancel{375} I_1 - 100 I_2 = 200$

$-\cancel{375} I_1 + 812.25\, I_2 = 750$

$712.25\, I_2 = 950$

$I_2 = \dfrac{950}{712.25} = 1.33\ A$

Putting 'I_2' in eq$^{\underline{n}}$ ①,

$37.5\, I_1 - 10(1.33) = 20$

$37.5\, I_1 - 13.3 = 20$

$37.5\, I_1 = 33.3$

$I_1 = \dfrac{33.3}{37.5} = 0.888\ A$

Current passing through $10\,\Omega$ resistor $= 10(1.33 - 0.888)$

$= 4.42\ A$

$I_{10}\,(20V)$

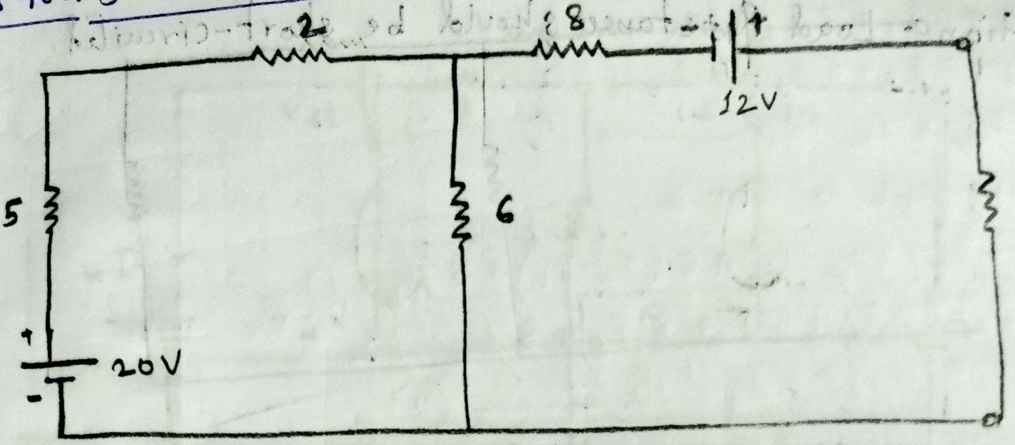
$I_{10}\,(\text{Total}) = I_{10}\,(50V) + I_{10}\,(30V) +$

$I_{10}\,(\text{Total}) = 0.42A + 0.522A + 4.42A$

$= 5.362A$

∴ Total current passing through the $10\,\Omega$ resistor because of all the sources is 5.362 A.

Norton's Theorem :-

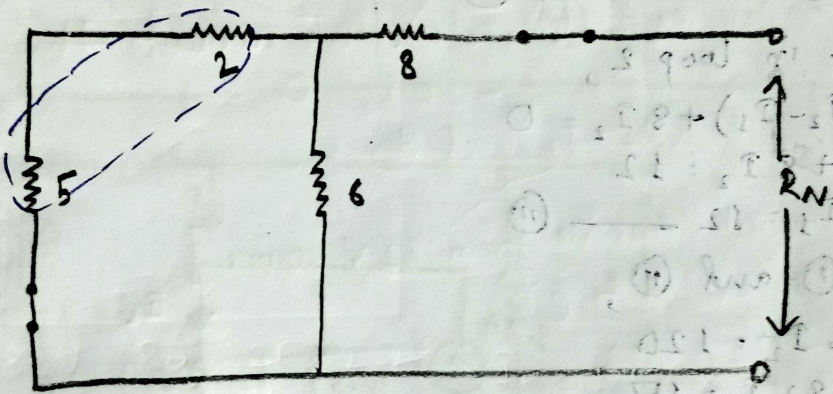


Step - I : R_N = Norton's Resistance

Conditions :-

- Load resistance should be open-circuited.
- Voltage source should be short-circuited.

1



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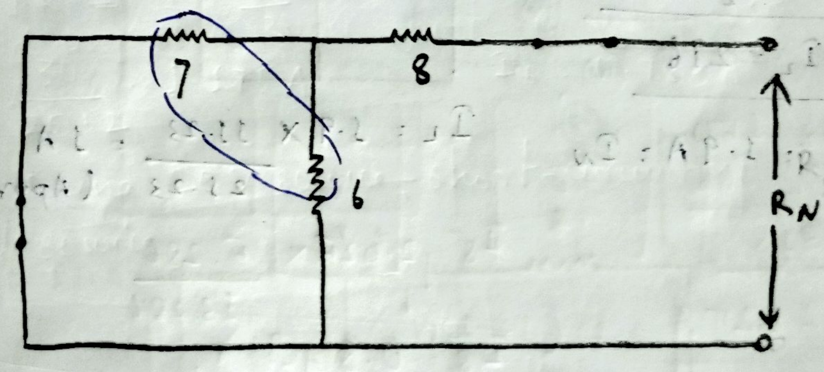

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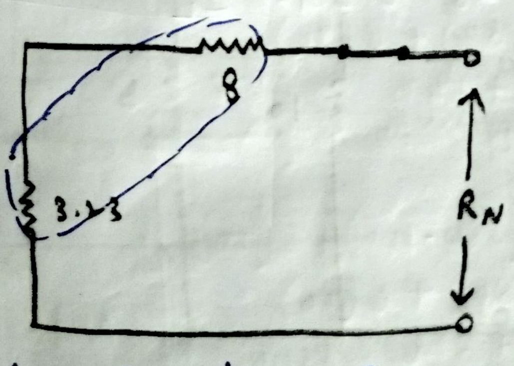

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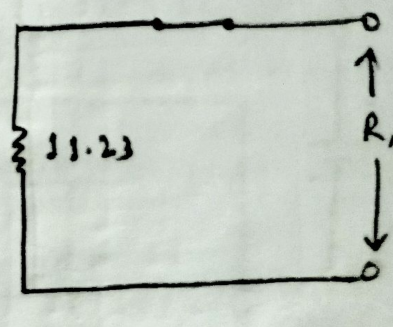
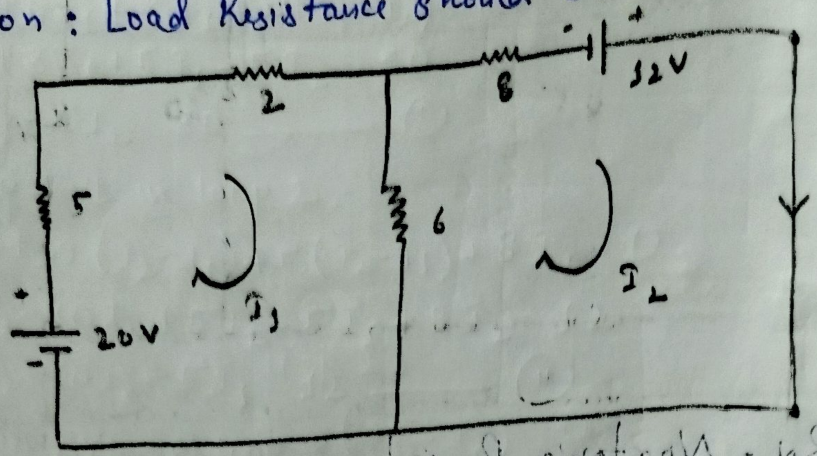


Norton's Resistance = R_N = $11.23\,\Omega$

Step - II : I_N = Norton's Current

Condition : Load Resistance should be short-circuited.



Applying KVL in loop 1,

$$-20 + 5I_1 + 2I_1 + 6(I_1 - I_2) = 0$$
$$5I_1 + 2I_1 + 6I_1 - 6I_2 = 20$$
$$13I_1 - 6I_2 = 20 \quad \text{——— (1)}$$

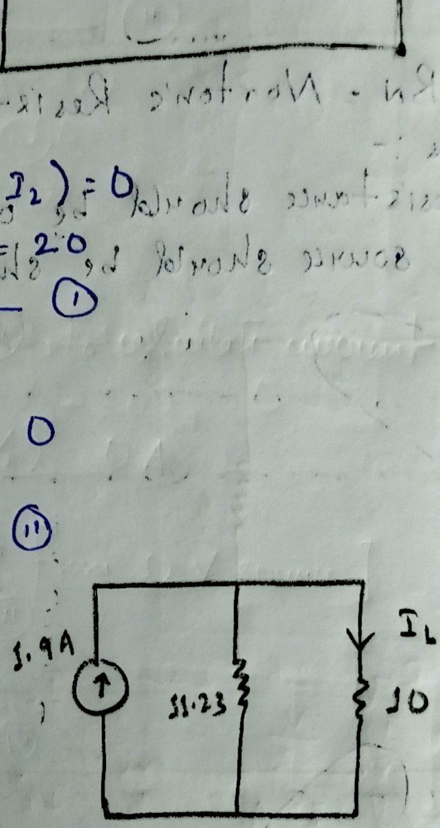
Applying KVL in loop 2,

$$-12 + 6(I_2 - I_1) + 8I_2 = 0$$
$$6I_2 - 6I_1 + 8I_2 = 12$$
$$14I_2 - 6I_1 = 12 \quad \text{——— (ii)}$$

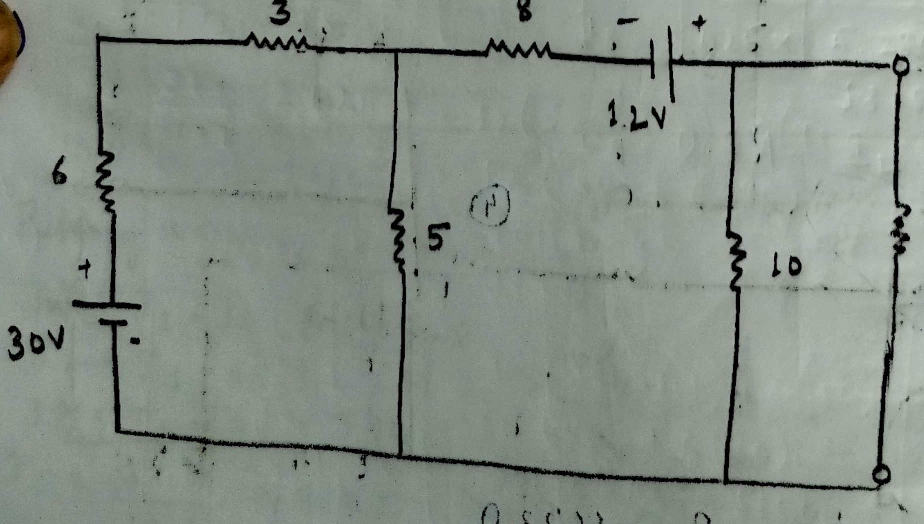
Solving eq^n (1) and (ii),

$$\cancel{78I_1} - 36I_2 = 120$$
$$-\cancel{78I_1} + 182I_2 = 156$$
$$146I_2 = 276$$

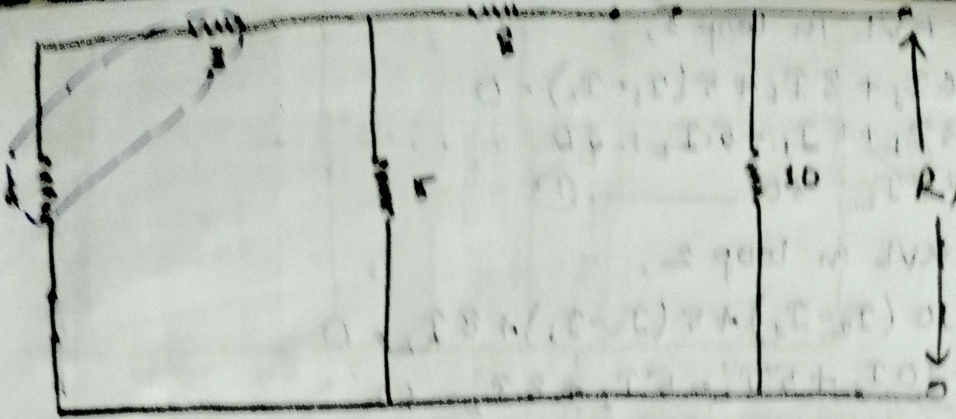
$$I_2 = \frac{276}{146} = 1.9A = I_N$$



$$I_L = 1.9 \times \frac{11.23}{21.23} = 1\,A \text{ (Approx)}$$



1



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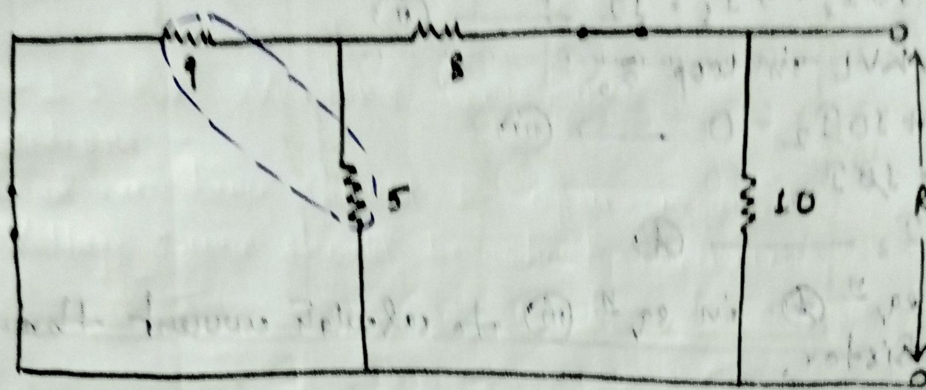

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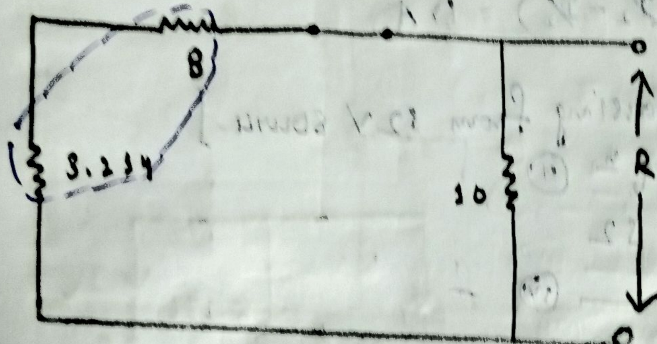
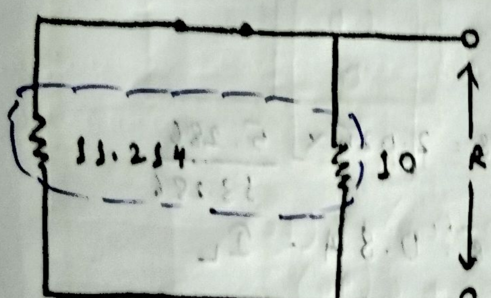


$R_N = 5.286\ \Omega$

4



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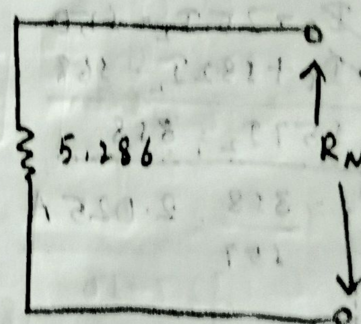
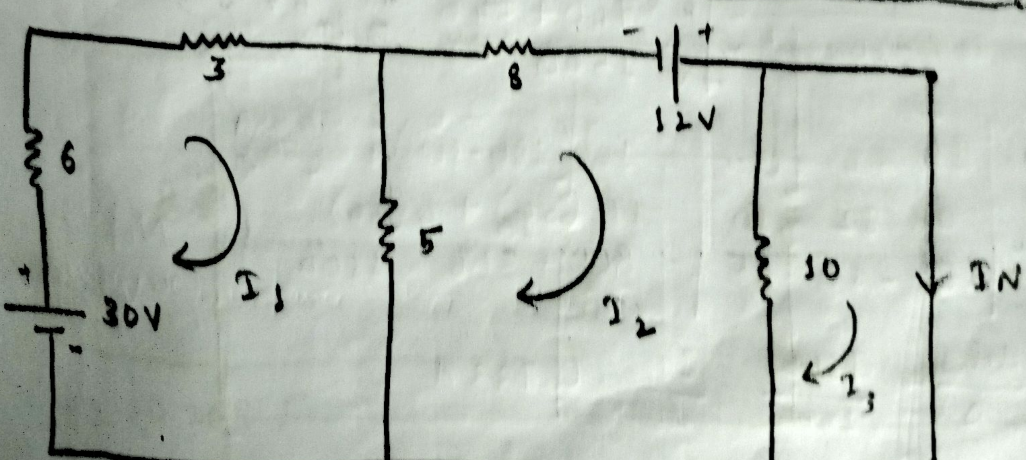




Applying KVL in loop 1,

$-30+6I_1+3I_1+5(I_1-I_2)=0$

$6I_1+3I_1+5I_1-5I_2=30$

$14I_1-5I_2=30$ —— (i)

Applying KVL in loop 2,

$-12+10(I_2-I_3)+5(I_2-I_1)+8I_2=0$

$10I_2-10I_3+5I_2-5I_1+8I_2=12$

$23I_2-10I_3-5I_1=12$ —— (ii)

Applying KVL in loop 3,

$-10I_3+10I_2=0$ —— (iii)

$\cancel{10}I_2=\cancel{10}I_3$

$I_2=I_3$ —— (A)

Putting eq^n (A) in eq^n (iii) to calculate current through 10Ω resistor,

$=10(I_2-I_3)=10(\cancel{I_2}-\cancel{I_2})=0\,A$

Thus,

$I_N=I_2$ [current passing from 12V source]

Putting eq^n (A) in eq^n (ii),

$23I_2-10I_2-5I_1=12$

$13I_2-5I_1=12$ —— (iv)

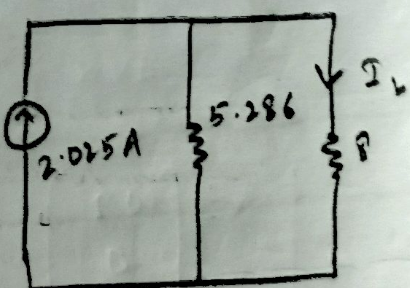
Solving eq^n (i) and (iv),

$70I_1-25I_2=150$

$-70I_1+182I_2=168$

$157I_2=318$

$I_2=\frac{318}{157}=2.025\,A$

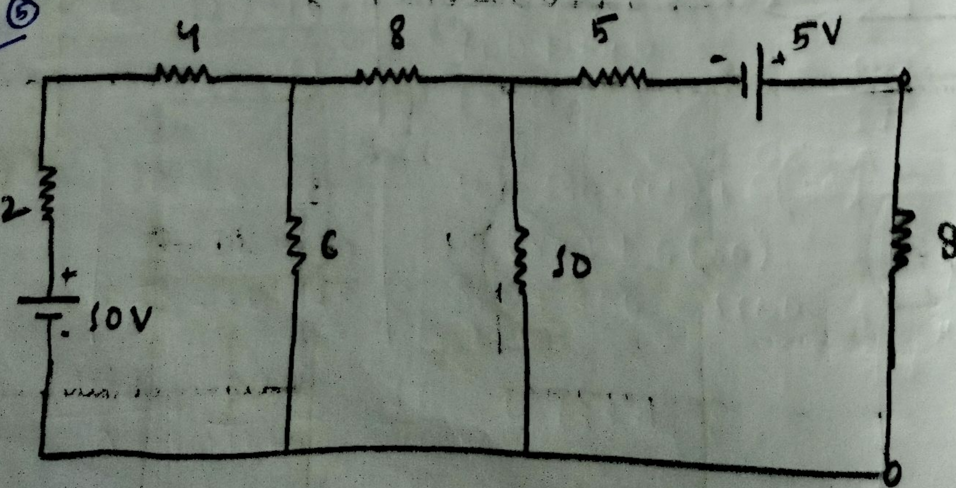


$I_8=2.025\times\frac{5.286}{13.286}$

$I_8=0.8\,A=I_L$

H.W (5)

Q)



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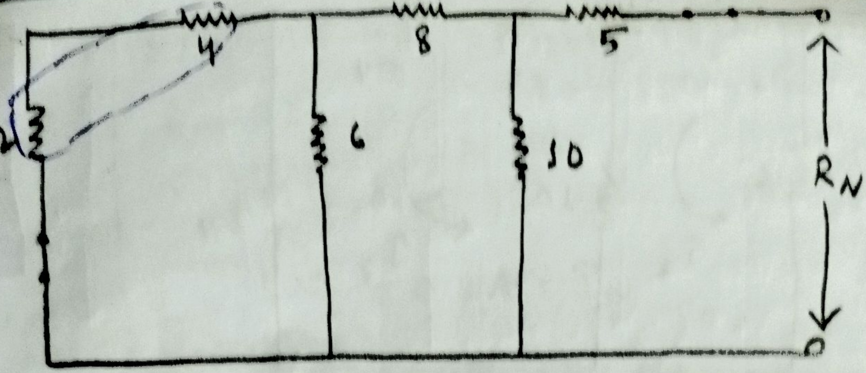

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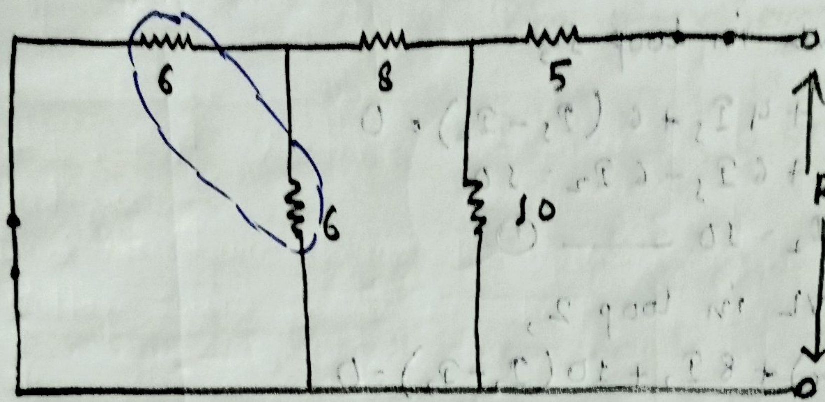

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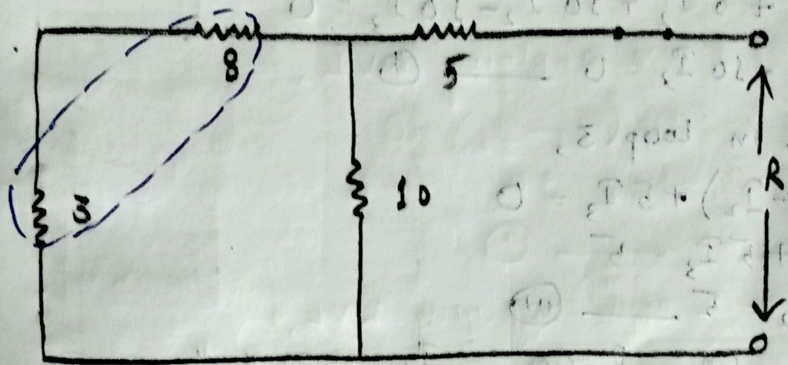

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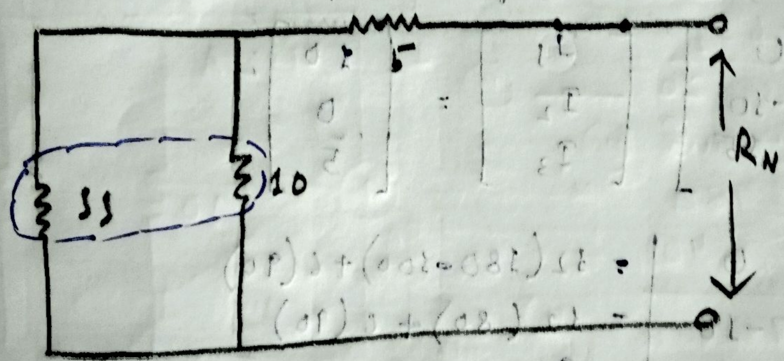

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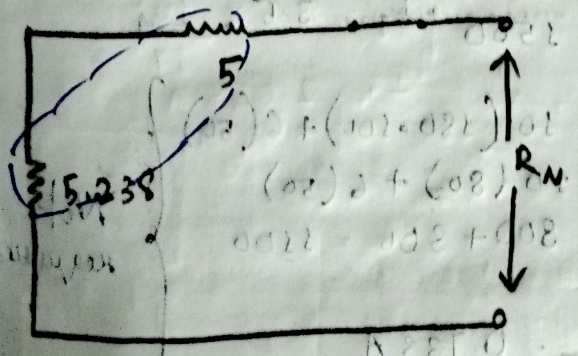

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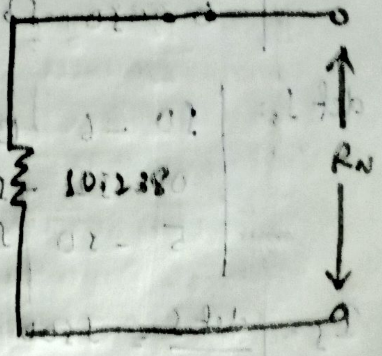
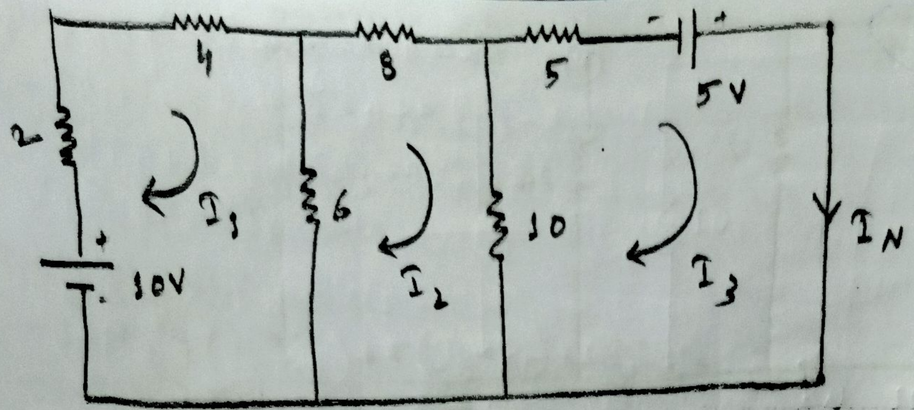


$R_N = 10.238\ \Omega$



Applying KVL in loop 1,

$$-10 + 2I_1 + 4I_1 + 6(I_1 - I_2) = 0$$
$$2I_1 + 4I_1 + 6I_1 - 6I_2 = 10$$
$$12I_1 - 6I_2 = 10 \text{ ——— } (\text{i})$$

Applying KVL in loop 2,

$$-6(I_2 - I_1) + 8I_2 + 10(I_2 - I_3) = 0$$
$$-6I_2 + 6I_1 + 8I_2 + 10I_2 - 10I_3 = 0$$
$$12I_2 + 6I_1 - 10I_3 = 0 \text{ ——— } (\text{ii})$$

Applying KVL in loop 3,

$$-5 + 10(I_3 - I_2) + 5I_3 = 0$$
$$10I_3 - 10I_2 + 5I_3 = 5$$
$$15I_3 - 10I_2 = 5 \text{ ——— } (\text{iii})$$

Solving eq^n (i), (ii) and (iii),

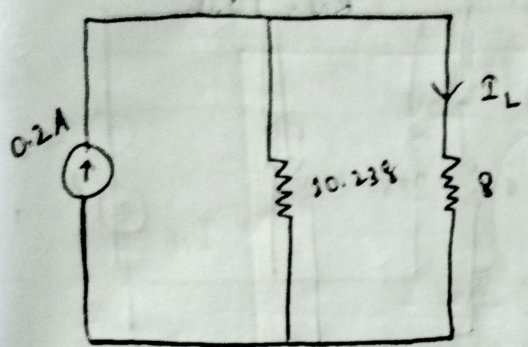
$$\begin{bmatrix} 12 & -6 & 0 \\ 6 & 12 & -10 \\ 0 & -10 & 15 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} 10 \\ 0 \\ 5 \end{bmatrix}$$

$$\Delta = \begin{vmatrix} 12 & -6 & 0 \\ 6 & 12 & -10 \\ 0 & -10 & 15 \end{vmatrix} \begin{aligned} &= 12(180-100) + 6(90) \\ &= 12(80) + 6(90) \\ &= 960 + 540 \\ &= 1500 \end{aligned}$$

$$\left.\begin{aligned} \det 1 = \begin{vmatrix} 10 & -6 & 0 \\ 0 & 12 & -10 \\ 5 & -10 & 15 \end{vmatrix} &= 10(180-100) + 6(50) \\ &= 10(80) + 6(50) \\ &= 800 + 300 = 1100 \\ I_1 = \frac{\det 1}{\Delta} = \frac{1100}{1500} &= \frac{11}{15} = 0.733 \text{ A} \end{aligned}\right\} \text{Not required}$$

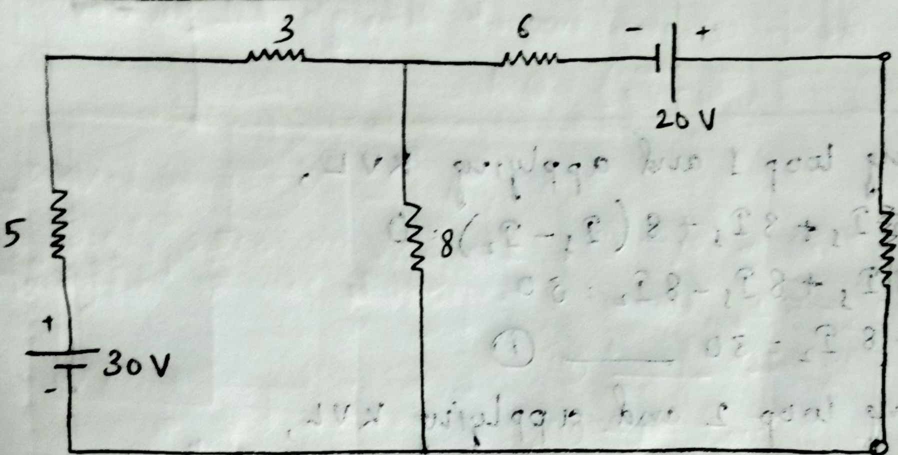
$$\text{det } 3 = \begin{vmatrix} 12 & -6 & 10 \\ 6 & 12 & 0 \\ 0 & -10 & 5 \end{vmatrix} = 12(60) + 6(30) + 10(-60)$$
$$= 720 + 180 - 600$$
$$= 300$$

$$I_3 = \frac{\text{det}_3}{\Delta} = \frac{300}{1500} = 0.2\text{A} = I_N$$

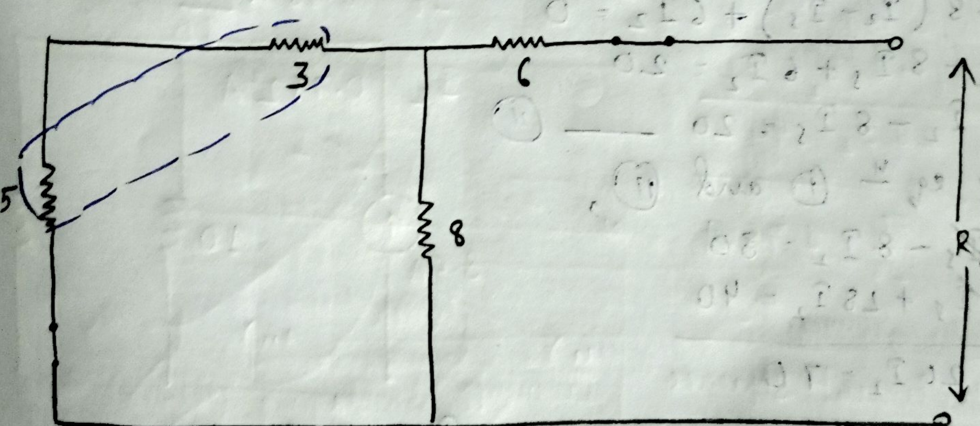


$$I_8 = 0.2 \times \frac{10.238}{18.238}$$
$$I_8 = \frac{2}{10} \times 0.56$$
$$I_L = 0.112\text{ A}$$

9)



1



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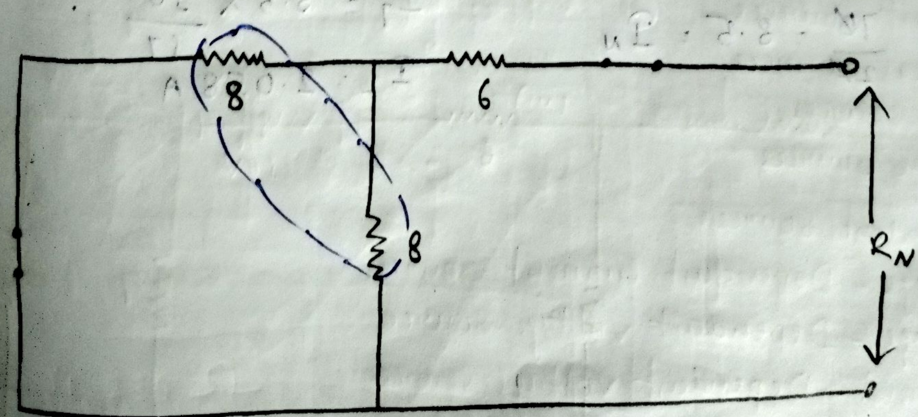
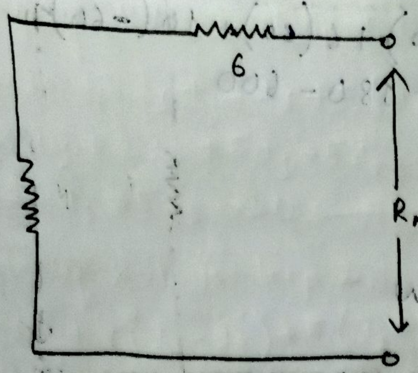
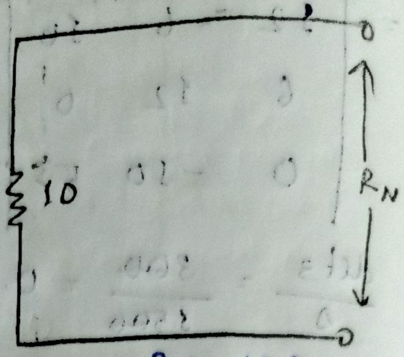


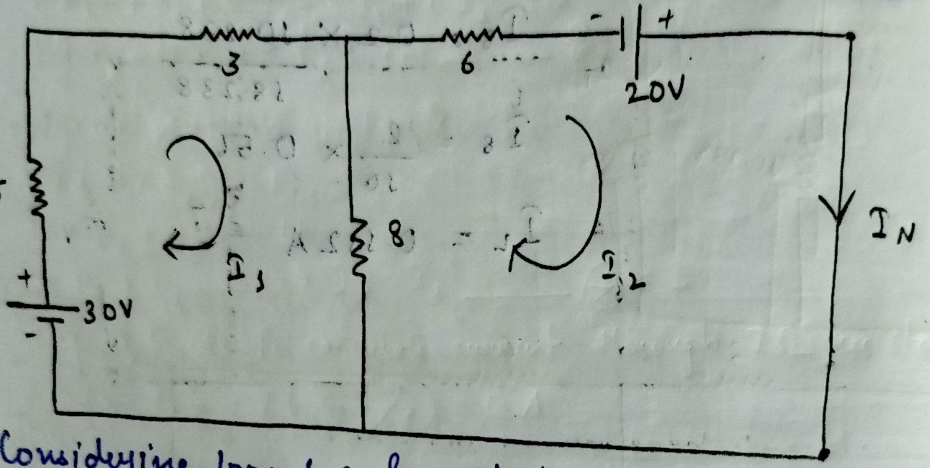
(3)



(4) :



$R_N = 10\Omega$



Considering loop 1 and applying KVL,

$$-30+5I_1+3I_1+8(I_1-I_2)=0$$

$$5I_1+3I_1+8I_1-8I_2=30$$

$$16I_1-8I_2=30 \quad \text{—— (i)}$$

Considering loop 2 and applying KVL,

$$-20+8(I_2-I_1)+6I_2=0$$

$$8I_2-8I_1+6I_2=20$$

$$14I_2-8I_1=20 \quad \text{—— (ii)}$$

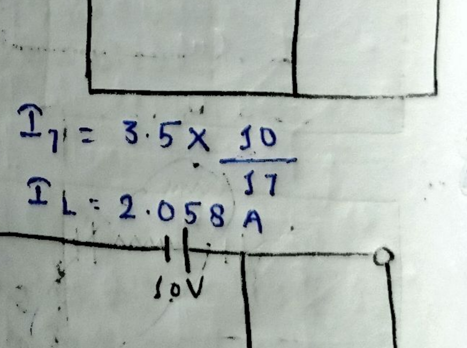
Solving eqn (i) and (ii),

$$\cancel{16I_1}-8I_2=30$$

$$-\cancel{16I_1}+28I_2=40$$

$$20I_2=70$$

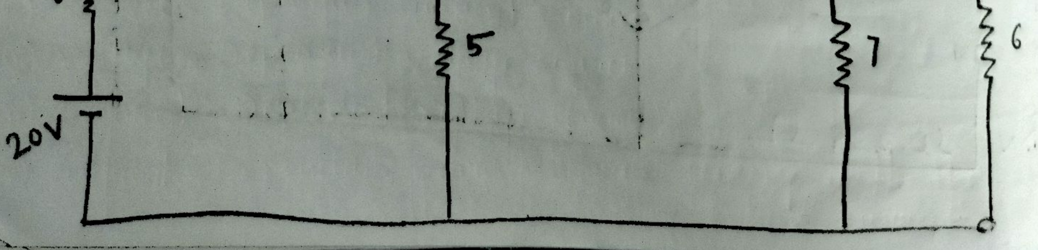
$$I_2=\frac{70}{20}=3.5=I_N$$



$$I_7 = 3.5\times\frac{10}{17}$$

$$I_L = 2.058\text{ A}$$

Q)



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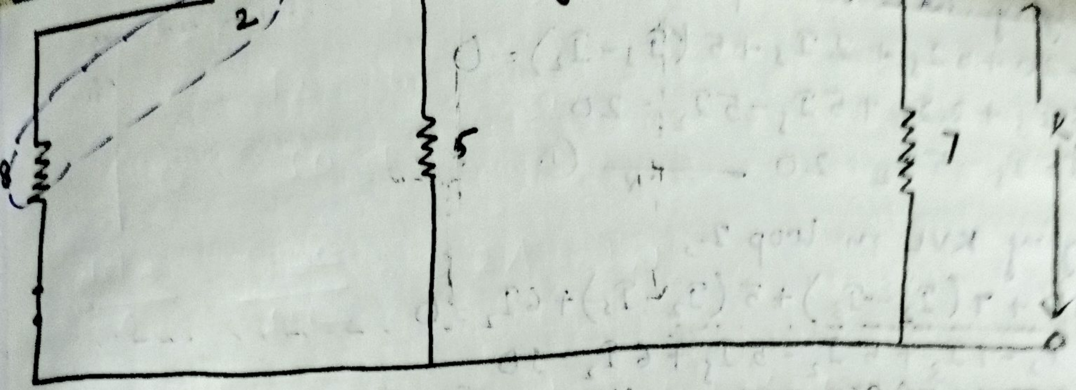

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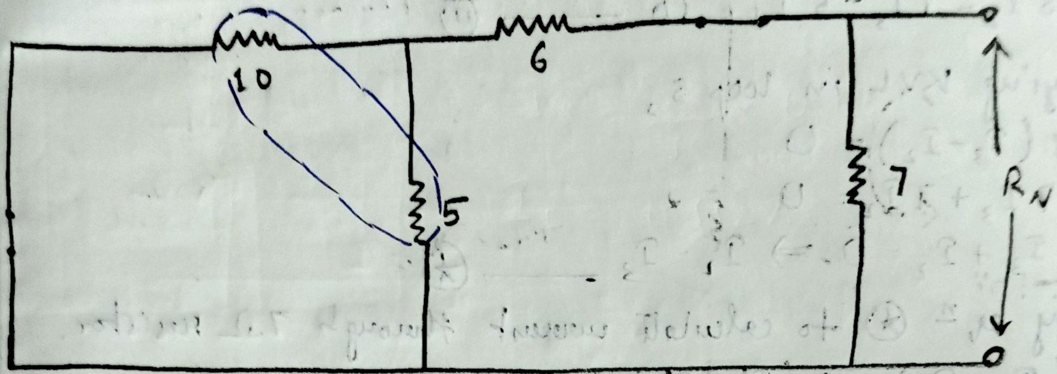

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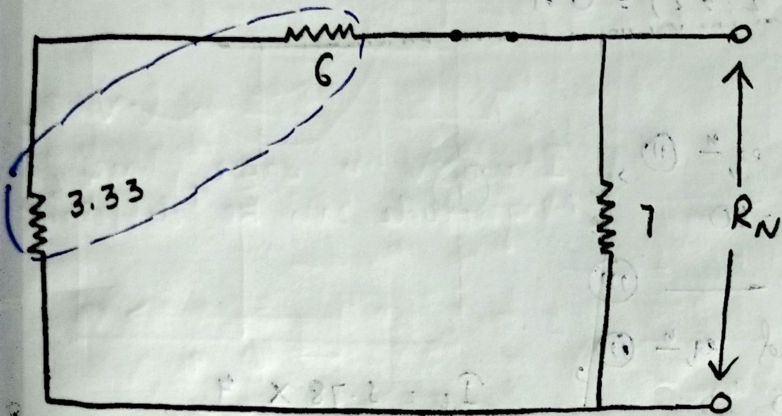
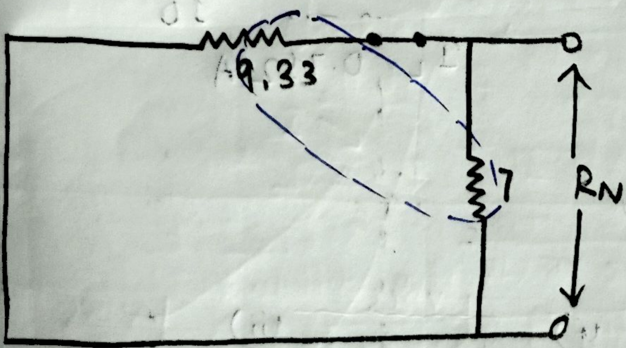


$R_N = 4\,\Omega$

④



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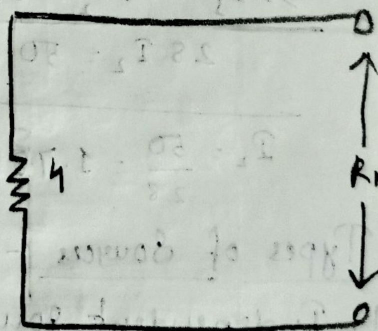
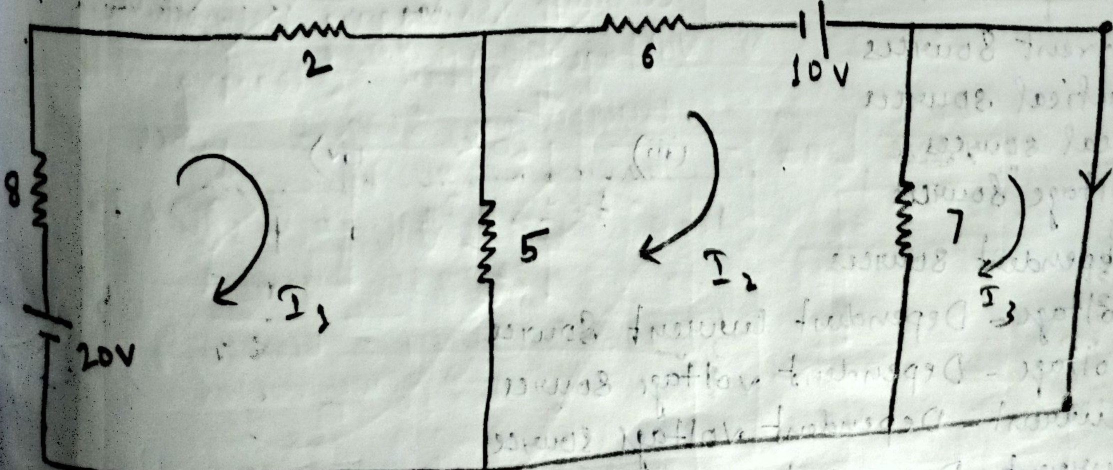




Applying KVL in loop 1,

$-20 + 8I_1 + 2I_1 + 5(I_1 - I_2) = 0$

$8I_1 + 2I_1 + 5I_1 - 5I_2 = 20$

$15I_1 - 5I_2 = 20$ ——— (i)

Applying KVL in loop 2,

$-10 + 7(I_2 - I_3) + 5(I_2 - I_1) + 6I_2 = 0$

$7I_2 - 7I_3 + 5I_2 - 5I_1 + 6I_2 = 10$

$18I_2 - 7I_3 - 5I_1 = 10$ ——— (ii)

Applying KVL in loop 3,

$-7(I_3 - I_2) = 0$

$-7I_3 + 7I_2 = 0$

$-I_3 + I_2 = 0 \Rightarrow I_2 = I_3$ ——— (*)

Using eq^n (*) to calculate current through 7Ω resistor.

$= 7(I_2 - I_3) = 7(\cancel{I_2} - \cancel{I_2}) = 0\,A$

Thus,

$I_2 = I_N$

Putting eq^n (*) in eq^n (ii),

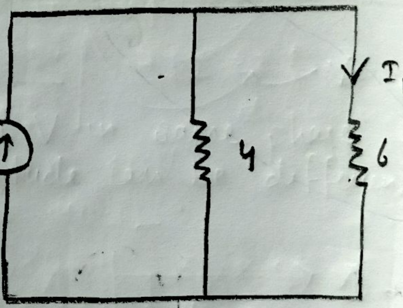
$18I_2 - 7I_2 - 5I_1 = 10$

$11I_2 - 5I_1 = 10$ ——— (iii)

Solving eq^n (i) and eq^n (iii),

$$\begin{aligned} \cancel{15I_1} - 5I_2 &= 20 \\ -\cancel{15I_1} + 33I_2 &= 30 \\ \hline 28I_2 &= 50 \end{aligned}$$

$I_2 = \frac{50}{28} = 1.78\,A = I_N$



$I_6 = 1.78 \times \frac{4}{10}$

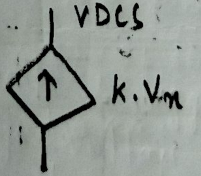
$I_L = 0.712\,A$

Types of Sources :-

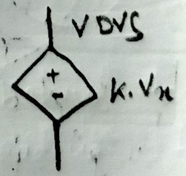
(I) Independent sources
(i) Current Sources
- Practical sources
- Ideal sources
(ii) Voltage Sources

(II) Dependent sources
(i) Voltage - Dependent Current Source
(ii) Voltage - Dependent voltage source
(iii) Current - Dependent voltage source
(iv) Current - Dependent current source

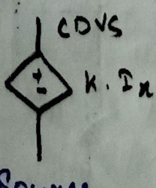
(i)



(ii)



(iii)



(iv)