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Preface

B. Singh (Ex. IES)

Civil Service is considered as the most prestigious job in India and it has become a preferred destination by all engineers. In order to reach this estimable position every aspirant has to take arduous journey of Civil Services Examination (CSE). Focused approach and strong determination are the pre-requisites for this journey. Besides this, a good book also comes in the list of essential commodity of this odyssey.

I feel extremely glad to launch the revised edition of such a book which will not only make CSE plain sailing, but also with 100% clarity in concepts.

MADE EASY team has prepared this book with utmost care and thorough study of all previous years papers of CSE. The book aims to provide complete solution to all previous years questions with accuracy.

On doing a detailed analysis of previous years CSE question papers, it came to light that a good percentage of questions have been asked in Engineering Services, Indian Forest Services and State Services exams. Hence, this book is a one stop shop for all CSE/IRMSE, ESE and other competitive exam aspirants.

I would like to acknowledge efforts of entire MADE EASY team who worked day and night to solve previous years papers in a limited time frame and I hope this book will prove to be an essential tool to succeed in competitive exams and my desire to serve student fraternity by providing best study material and quality guidance will get accomplished.

With Best Wishes
B. Singh (Ex. IES)
CMD, MADE EASY Group

Previous Years Solved Papers of

Civil Services Main Examination

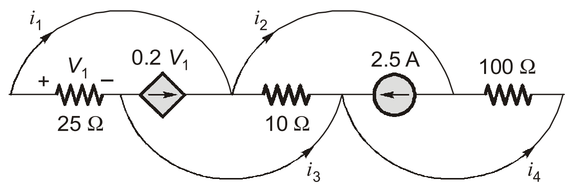
Electrical Engineering : Paper-I

CONTENTS

1 Circuit Theory

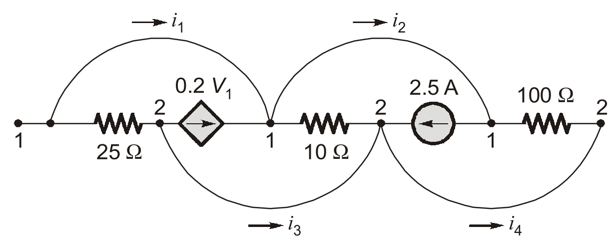
1. Circuit Element, Nodal and Mesh Analysis

1.1 For the circuit shown below, find i_1, i_2, i_3 and i_4.

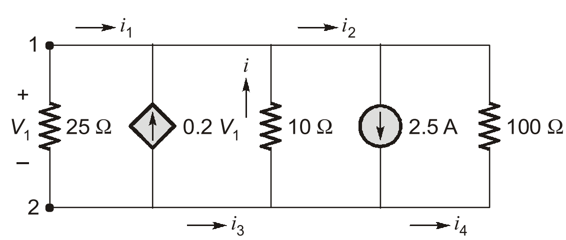


[CSE-2005 : 5 marks]

Solution:



Circuit is redrawn as:



By Nodal equation,

$$-\frac{V_1}{100} - 2.5 - \frac{V_1}{10} + 0.2V_1 - \frac{V_1}{25} = 0$$

$$\Rightarrow \quad V_1 = \frac{250}{5} = 50 \text{ V}$$

$$i_4 = -\frac{V_1}{100} = -0.5 \text{ A}$$

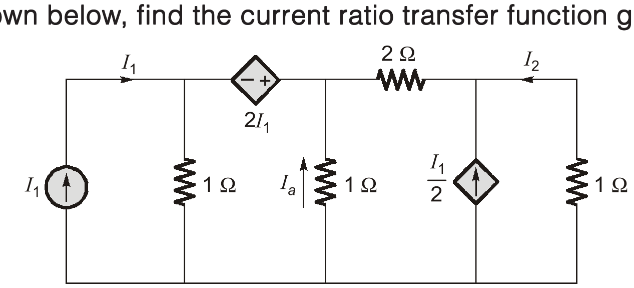
$$i_1 = -\frac{V_1}{25} = \frac{-50}{25} = -2 \text{ A}$$

$$i_2 = i_1 + 0.2\,V_1 + i = -2 + 10 - 5 = 3 \text{ A}$$

$$i_3 = i - 2.5 + i_4 = -5 - 2.5 - 0.5 = -8 \text{ A}$$

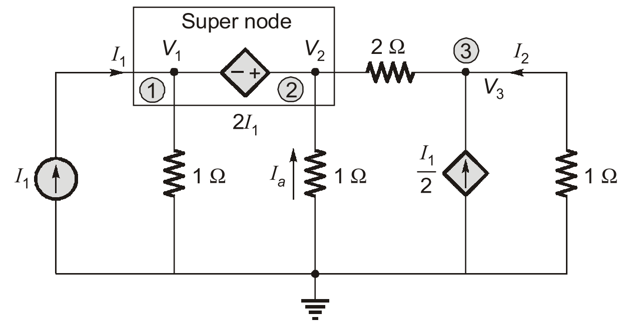
$$i_1 = -2 \text{ A} \;;\; i_2 = 3 \text{ A} \;;\; i_3 = -8 \text{ A} \;;\; i_4 = -0.5 \text{ A}$$

1.2 For the network shown below, find the current ratio transfer function given by $\alpha = I_2/I_1$.



[CSE-2005 : 10 marks]

Solution:



Consider nodes (1) and (2). These two nodes constitutes a super node.

$$V_2 - V_1 = 2I_1 \quad ...(1)$$

Super node equation

$$\frac{V_1}{1} - I_1 + \frac{V_2}{1} + \frac{V_2 - V_3}{2} = 0 \quad ...(2)$$

$$V_1 + V_2 + 0.5V_2 - 0.5V_3 = I_1$$

$$V_1 + 1.5V_2 - 0.5V_3 = I_1$$

Node (3):

$$\frac{V_3 - V_2}{2} - I_2 - \frac{I_1}{2} = 0 \quad ...(3)$$

Put $\frac{V_3 - V_2}{2} = 0.5I_1 + I_2$

$$V_1 - I_1 + V_2 - 0.5I_1 - I_2 = 0$$

$$V_1 + V_2 = 1.5I_1 + I_2 \quad ...(4)$$

From (1) and (4)

$$V_2 = 1.75I_1 + 0.5I_2$$

Also $V_3 - V_2 = I_1 + 2I_2$

$$V_3 = V_2 + I_1 + 2I_2$$

$$V_3 = 2.75I_1 + 2.5I_2 \quad ...(5)$$

Also $I_2 = -V_3$

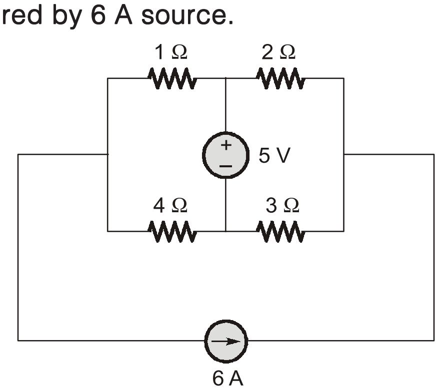
From (5),

$$-I_2 = 2.75I_1 + 2.5I_2$$

$$-3.5I_2 = 2.75I_1$$

$$\alpha = \frac{I_2}{I_1} = \frac{-2.75}{3.5} = -0.786$$

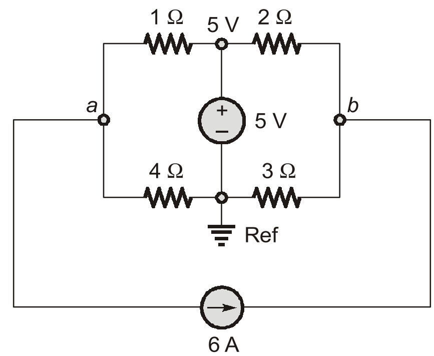
1.3 Determine the power delivered by 6 A source.



[CSE-2007 : 10 marks]

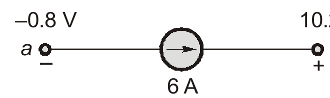
Solution:

Consider node a and b



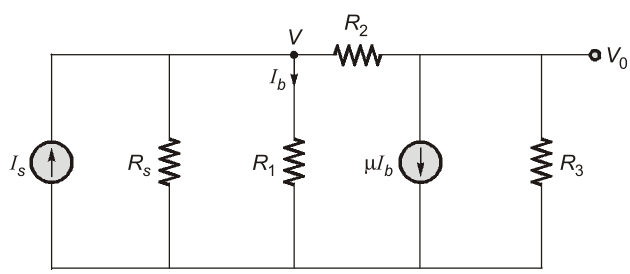
Node a:
$$\frac{V_a-5}{1}+\frac{V_a}{4}+6 = 0$$
$$V_a\left(1+\frac{1}{4}\right) = -1$$
$$\Rightarrow \quad V_a = -0.8\text{ V}$$

Node b:
$$\frac{V_b-5}{2}+\frac{V_b}{3}-6 = 0$$
$$V_b\left(\frac{1}{2}+\frac{1}{3}\right) = 8.5$$
$$\Rightarrow \quad V_b = 10.2\text{ V}$$



$$\text{Power supplied} = (V_{ba})(6) = (10.2+0.8)\,6$$
$$P = 66\text{ W}$$

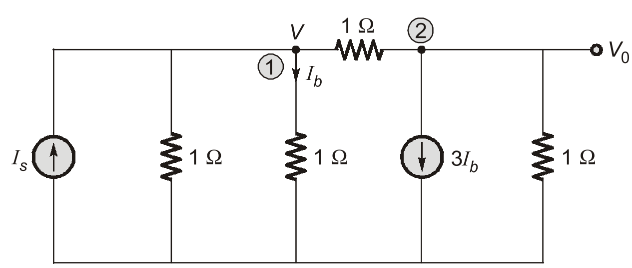
1.4 For the circuit shown in the figure determine V_0/I_S using nodal analysis.



$R_1 = R_2 = R_3 = R_s = 1\ \Omega$, $\mu = 3$

[CSE-2007 : 10 marks]

Solution:



$R_1 = R_2 = R_3 = R_s = 1\ \Omega$, $\mu = 3$

$$V = I_b \qquad \ldots(1)$$

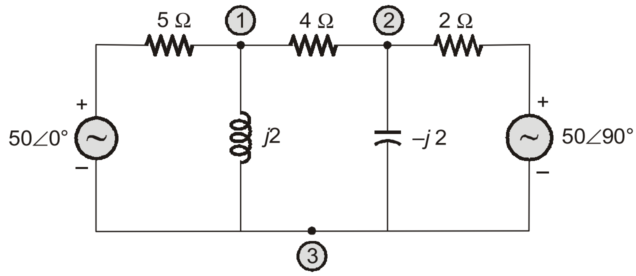
Node (1),
$$\frac{V}{1}+\frac{V}{1}+\frac{V-V_0}{1}-I_s = 0$$
$$3V-V_0 = I_s \qquad \ldots(2)$$

Node (2),
$$\frac{V_0}{1}+\frac{V_0-V}{1}+3I_b = 0$$
$$2V_0-V = -3I_b \qquad \ldots(3)$$

From equation (1), $I_b = V$ put in equation (3)
$$2V_0-V = -3\text{ V}$$
$$2V_0 = -2\text{ V}$$
$$\Rightarrow \quad V = -V_0$$

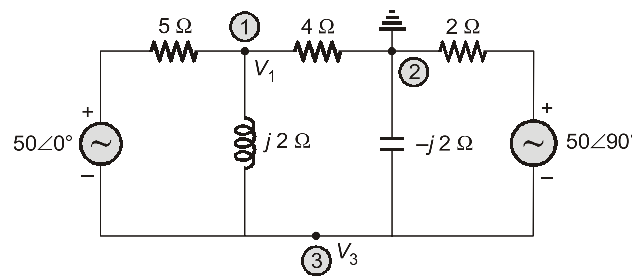
Putting, $V = -V_0$ in equation (2)
$$3(-V_0)-V_0 = I_s$$
$$-4V_0 = I_s$$
$$\frac{V_0}{I_s} = -\frac{1}{4} = -0.25$$

1.5 Write the node equations for the network shown in figure. Assume node (2) as a reference node.



[CSE-2010 : 10 marks]

Solution:



Node 1:

$$\frac{V_1 - V_3 - 50}{5} + \frac{V_1 - V_3}{j2} + \frac{V_1}{4} = 0$$

$$V_1(0.2 + 0.25 - j\,0.5) - V_3(0.2 - j\,0.5) = 10 \quad \ldots(1)$$

Node 3:

$$\frac{V_3 - V_1 + 50}{5} + \frac{V_3 - V_1}{j2} + \frac{V_3}{-j2} + \frac{V_3 + j50}{2} = 0$$

$$V_3\left(\frac{1}{5} + \frac{1}{j2} - \frac{1}{j2} + \frac{1}{2}\right) - \frac{V_1}{5} - \frac{V_1}{j2} + 10 + j25 = 0$$

$$V_3(0.7) - V_1(-j\,0.5 + 0.2) = -10 - j\,25$$

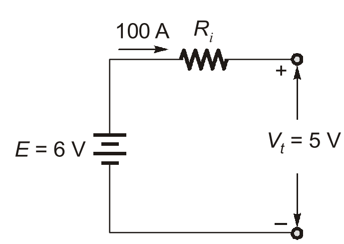
$$V_1(0.2 - j\,0.5) - 0.7V_3 = 10 + j\,25 \quad \ldots(2)$$

Nodal equation given by (1) and (2).

1.6 A storage battery has a no-load terminal voltage of 6 V. When the current through the battery is 100 A, the terminal voltage drops to 5 V. Show a pictorial representation of the battery as a constant current source.

[CSE-2011 : 15 marks]

Solution:

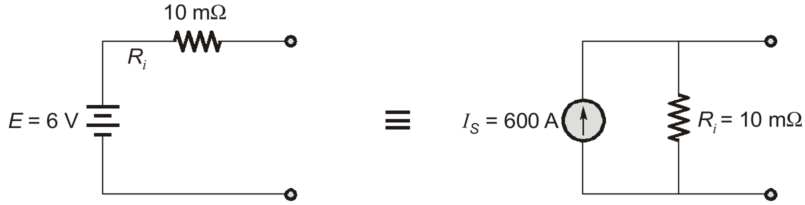


E = Open voltage of battery = 6 V with a current of 100 A

$$V_t = E - (100)\,R_i$$

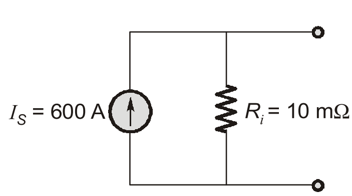
$$V_t = 5\text{ V} = 6 - 100\,R_i$$

$$R_i = 10\text{ m}\Omega$$

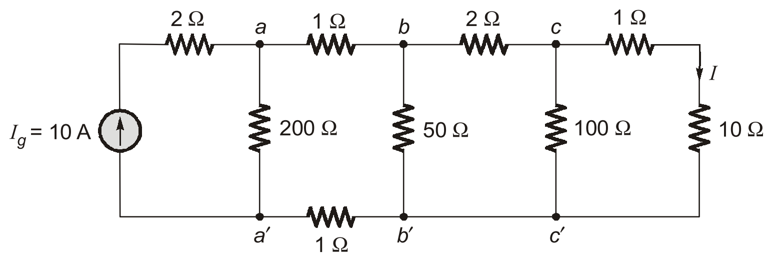


$$I_S = \frac{E}{R_i} = \frac{6}{10 \times 10^{-3}} = 600\text{ A}$$

Constant current source,



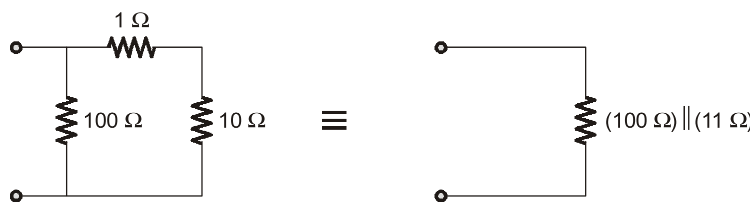
1.7 Determine the current-I in figure using the ladder reduction method.



[CSE-2013 : 20 marks]

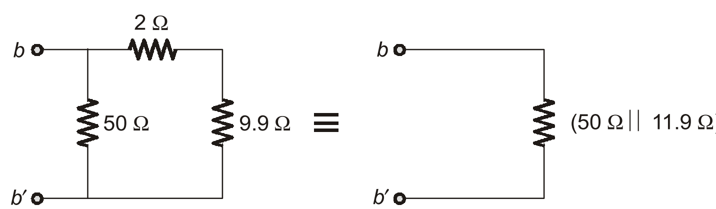
Solution:

First we will determine equivalent resistance across *cc′*



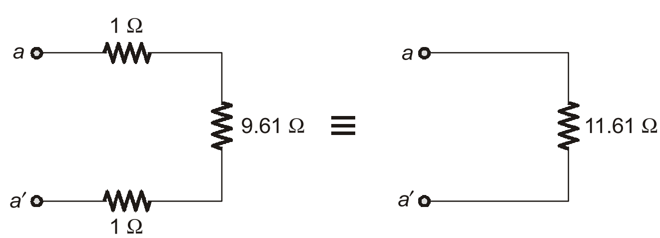
$$= \frac{1100}{11} = 9.9\,\Omega$$

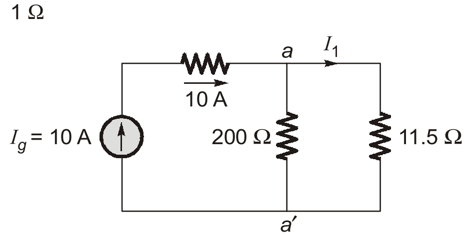
Equivalent resistance across *bb′*



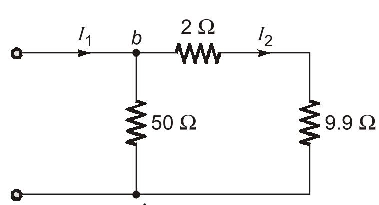
$$= \frac{(9.9+2)(50)}{9.9+2+50} = 9.61\,\Omega$$

Equivalent resistance across *aa′*

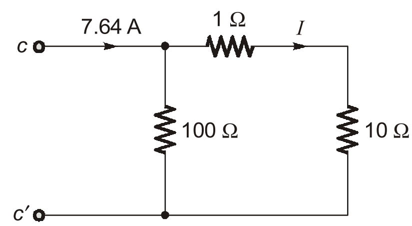




$$I_1 = \frac{(10)(200)}{200+11.5} = 9.46\,\text{A}$$

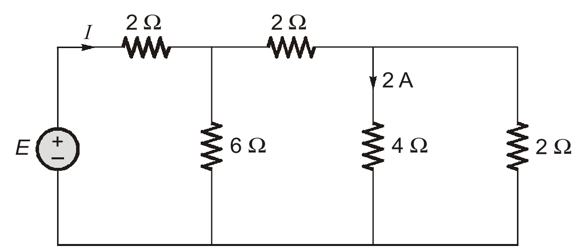


$$I_2 = \frac{(I_1)(50)}{50+2+9.9} = \frac{9.46\times 50}{61.9} = 7.64\text{ A}$$



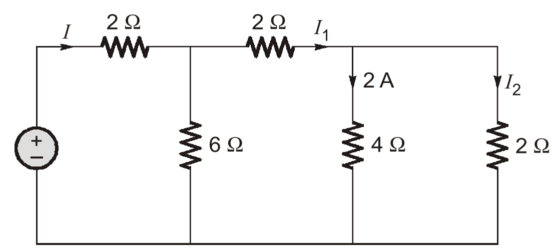
$$I = \frac{(7.64)(100)}{100+10+1} = 6.88\text{ A}$$

1.8 Find the values of E and I in the circuit shown in figure.



[CSE-2014 : 10 marks]

Solution:

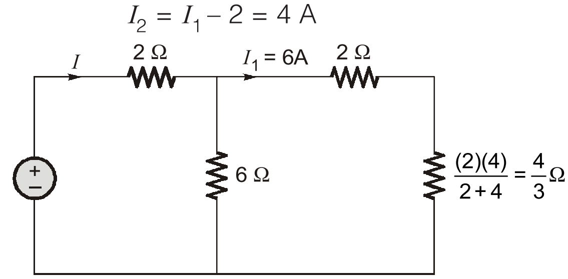


By the rule of division of current in parallel circuit

$$2 = \frac{(2)(I_1)}{2+4}$$

$\Rightarrow$ $I_1 = 6\text{ A}$

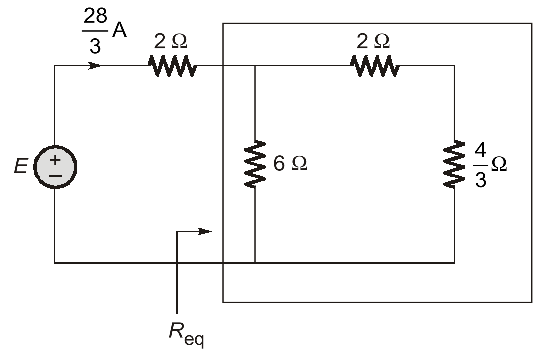
$$I_2 = I_1 - 2 = 4\text{ A}$$

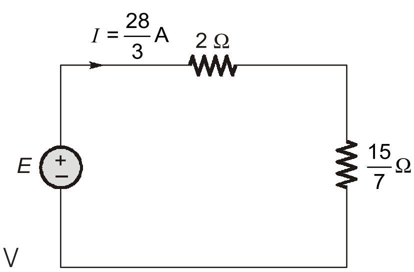


$$\frac{(2)(4)}{2+4} = \frac{4}{3}\Omega$$

$$I_1 = \frac{I(6)}{6+\left(2+\frac{4}{3}\right)} = \frac{I(18)}{18+6+4} = \frac{I(18)}{28}$$

$$I_1 = 6\text{ A} = I\frac{(18)}{28} \Rightarrow I = \frac{28}{3}\text{A}$$





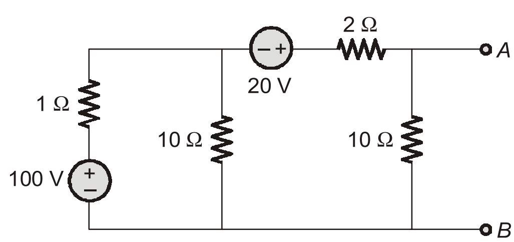
$$R_{eq} = \frac{(6)\left(\frac{10}{3}\right)}{6+\frac{10}{3}} = \frac{60}{28} = \frac{15}{7}\,\Omega$$

$$(I)\left(2+\frac{15}{7}\right) = E$$

$$E = \left(\frac{29}{7}\right)\left(\frac{28}{3}\right) = \frac{(29)(4)}{3} = 38.67 \text{ V}$$

$$I = \frac{28}{3} = 9.33 \text{ A}$$

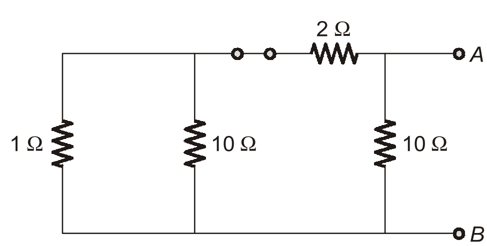
1.9 Obtain the Norton's equivalent circuit at the terminals *A* and *B* for the network shown in figure.



[CSE-2014 : 20 marks]

Solution:

R_N: Calculate same way as R_{th}. Short all independent voltage source



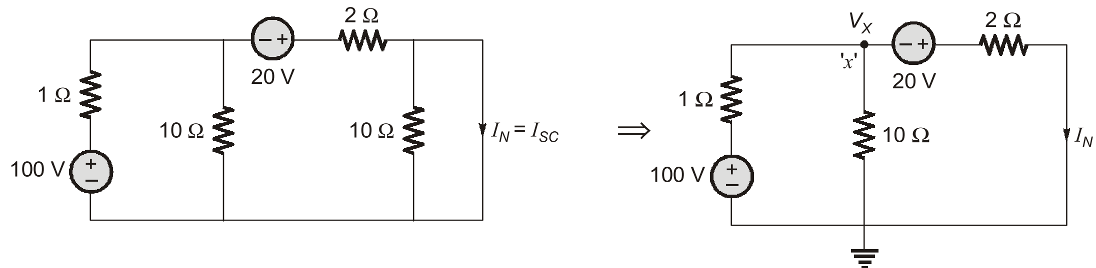
$$(1\Omega \parallel 10\Omega) = \frac{10}{11}\Omega$$

$$2\ \Omega \text{ in series with } \frac{10}{11}\Omega = \frac{32}{11}\Omega$$

$$R_N = R_{AB} = (10\,\Omega) \parallel \left(\frac{32}{11}\Omega\right) = \frac{(10)\left(\frac{32}{11}\right)}{10+\frac{32}{11}} = \frac{320}{142}$$

$$R_N = 2.25\ \Omega$$

I_N: Short terminal AB to get $I_{SC} = I_N$



Consider node (x) equation,

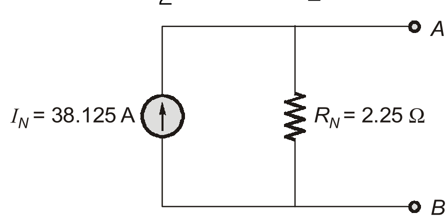
$$\frac{V_x - 100}{1} + \frac{V_x}{10} + \frac{V_x + 20}{2} = 0$$

$$V_x\left(1 + \frac{1}{10} + \frac{1}{2}\right) - 100 + 10 = 0$$

$$V_x(1 + 0.1 + 0.5) = 90$$

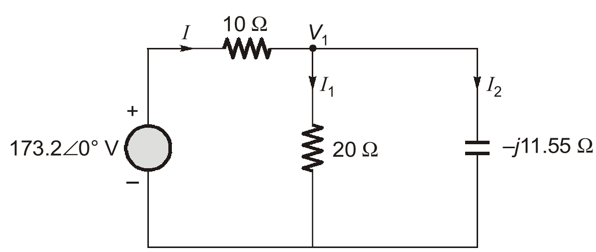
$$V_x = 56.25 \text{ V}$$

$$I_N = \frac{V_x + 20}{2} = \frac{56.25 + 20}{2} = 38.125 \text{ A}$$



Norton equivalent

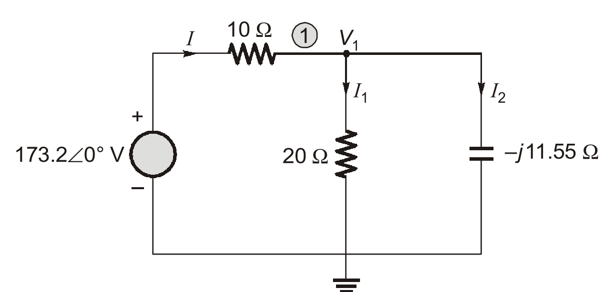
1.10 For the circuit shown in figure, evaluate the current through and the voltage across each element.



[CSE-2015 : 10 marks]

Solution:

Nodal equation of node (1):



$$\frac{V_1 - 173.2}{10} + \frac{V_1}{20} + \frac{V_1}{-j11.55} = 0$$

$$V_1\left(\frac{1}{10} + \frac{1}{20} - \frac{1}{j11.55}\right) = 17.32$$

$$V_1(0.1 + 0.05 + j0.0866) = 17.32$$

$$V_1(0.15 + j0.0866) = 17.32$$

$$V_1(0.1732\angle 30°) = 17.32$$

$$V_1 = 100\angle{-30°} \text{ V}$$

$$I_1 = \frac{V_1}{20} = \frac{100}{20}\angle -30° = 5\angle -30° \text{ A}$$

$$I_2 = \frac{V_1}{-j11.55} = \frac{100\angle -30°}{11.55\angle -90°} = 8.66\angle 60° \text{ A}$$

$$I = \frac{173.2 - 100\angle -30°}{10} = \frac{173.2 - 86.6 + j50}{10} = \frac{100\angle 30°}{10} = 10\angle 30° \text{ A}$$

$$V_{10\,\Omega} = 173.2\angle 0° - 100\angle -30° = 100\angle 30°$$

$$I_1 = 5\angle -30° \text{ A}$$

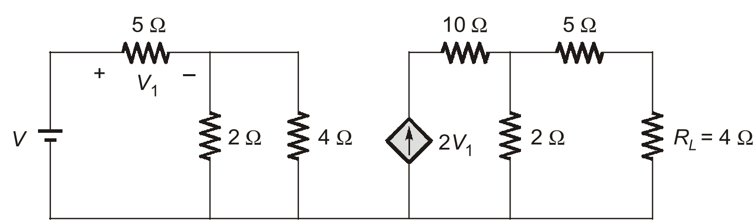
$$I_2 = 8.66\angle 60° \text{ A}$$

$$I = 10\angle 30° \text{ A}$$

$$V_1 = 100\angle -30° \text{ V}$$

$$V_{10\,\Omega} = 100\angle 30° \text{ V}$$

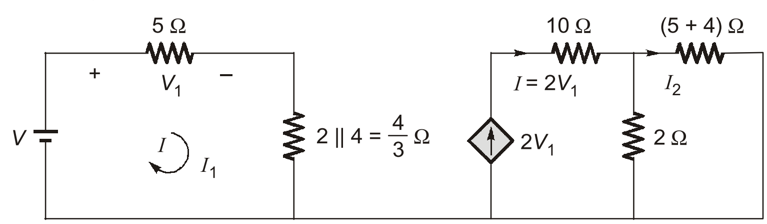
1.11 For the circuit shown in figure. Find the value of V if the power dissipated in the load resistance R_L is 36 Watts.



[CSE-2016 : 20 marks]

Solution:

The circuit can be drawn as,



Applying KVL in loop (1),

$$-V + 5I_1 + \frac{4}{3}I_1 = 0$$

$$V = \frac{19}{3}I_1 \Rightarrow I_1 = \frac{3V}{19}$$

$$V_1 = 5\,I_1 = 5 \times \frac{3V}{19} = \frac{15}{19}V \qquad \text{...(1)}$$

Now, using current division rule in I_2 loop,

$$I_2 = I \times \frac{2}{2+9} = 2V_1 \times \frac{2}{11} = \frac{4}{11}V_1 \qquad \text{...(2)}$$

This current will flow in load resistance R_l'.

∴ Power dissipation in load R_L, $P = I_2^2 \cdot R_L$

∴ $P = \left(\frac{4}{11}V_1\right)^2 \cdot 4$ From equation (2)

∴ $P = \left(\frac{4}{11} \times \frac{15}{19}V\right)^2 \cdot 4$ From equation (1)

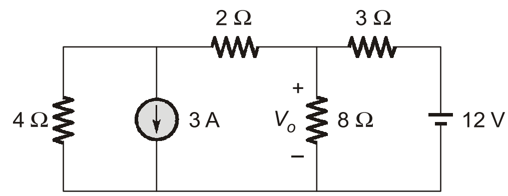
∴ $P = 0.08241 \times 4V^2 = 0.33\ V^2$

Given, $P = 36$ W

∴ $0.33\,V^2 = 36$ W

∴ $V = \sqrt{\dfrac{36}{0.33}} = 10.45$ V

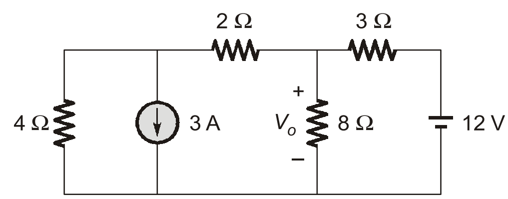
1.12 In the circuit shown in figure, find the voltage V_o across the 8 Ω resistor.



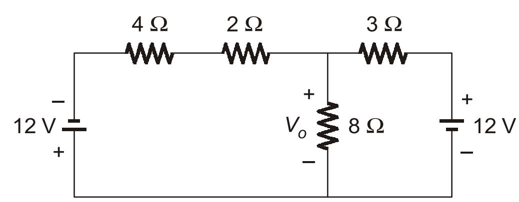
[CSE-2018 : 10 marks]

Solution:

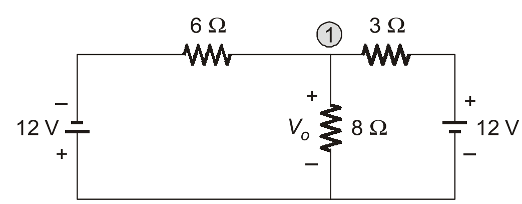
The given circuit is



The above circuit can be transformed into the circuit as (current source to voltage source transformation)



The equivalent circuit is as



Applying the KVL at node (1)

$$\frac{V_o + 12}{6} + \frac{V_o}{8} + \frac{V_o - 12}{3} = 0$$

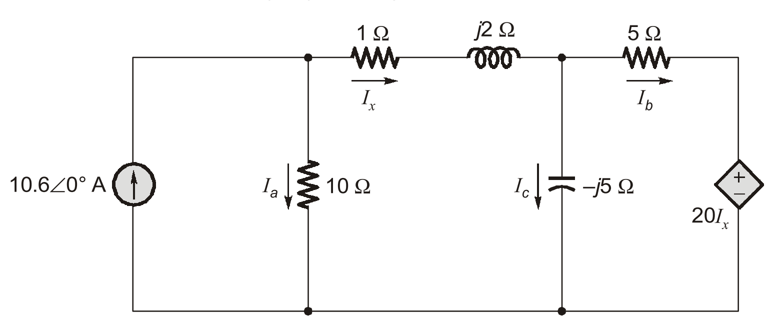
$$4V_o + 48 + 3V_o + 8V_o - 96 = 0$$

$$15V_o = 48$$

$$V_o = \frac{48}{15} = 3.2 \text{ V}$$

Hence, the voltage V_o across the 8 Ω resistor is 3.2 V.

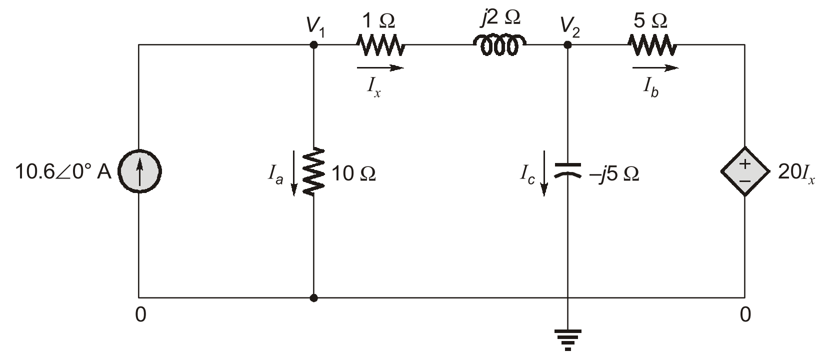
1.13 Find the values of branch currents I_a, I_b and I_c as indicated in the circuit shown below.



[CSE-2020 : 10 marks]

Solution:

Given circuit :



Applying KCL at node V_1, we get

$$10.6\angle 0^\circ = \frac{V_1}{10} + \frac{V_1 - V_2}{1 + j2}$$

$$\Rightarrow \quad V_1\left[\frac{1}{10} + \frac{1}{1+j2}\right] - \frac{V_2}{1+j2} = 10.6\angle 0^\circ$$

$$(0.3 - 0.4i)V_1 - (0.2 - 0.4i)V_2 = 10.6\angle 0^\circ \quad \text{...(1)}$$

$$\frac{V_1 - V_2}{1+j2} = I_x \quad \text{...(2)}$$

Applying KCL at node V_2, we get

$$\frac{-V_2}{j5} + \frac{V_2 - V_1}{1+j2} + \frac{V_2 - 20I_x}{5} = 0$$

$$\frac{-V_2}{j} + \frac{5(V_2 - V_1)}{1+j2} + V_2 - 20\left[\frac{V_1 - V_2}{1+j2}\right] = 0$$

$$V_2\left[\frac{-1}{j} + \frac{5}{1+j2} + 1 + \frac{20}{1+j2}\right] - V_1\left[\frac{5}{1+j2} + \frac{20}{1+j2}\right] = 0$$

$$-V_1(5 - 10j) + (6 - 9j)V_2 = 0$$

$$V_1 = \frac{(6-9j)}{(5-10j)}V_2 \Rightarrow (0.96 + 0.12j)V_2 \quad \text{...(2)}$$

From (1) and (2)

$$(0.3 - 0.4j)(0.96 + 0.12j)V_2 - (0.2 - 0.4j)V_2 = 10.6\angle 0^\circ$$

$$V_2 = 72.80\angle{-20.92^\circ}\text{ V}$$

$$V_1 = 70.43\angle{-13.80^\circ}\text{ V}$$

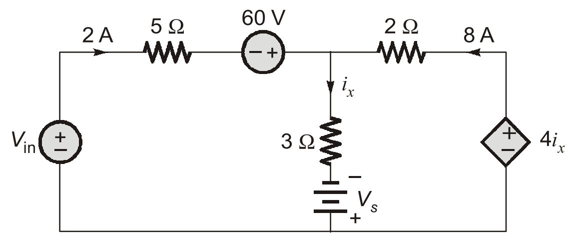
$$I_a = \frac{V_1}{10} = 7.043\angle{-13.80^\circ}\text{ A}$$

$$I_c = \frac{V_2}{-j5} = \frac{72.80\angle -20.92^\circ}{-5j} = 14.56\angle 69.08^\circ\text{ A}$$

$$I_x = \frac{V_1 - V_2}{1+j2} = 4.11\angle 24^\circ\text{ A}$$

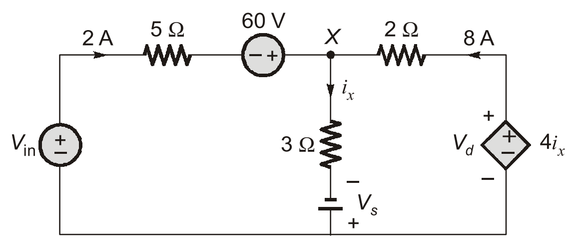
$$I_b = I_x - I_c = 12.01\angle{-96.90^\circ}\text{ A}$$

1.14 For the circuit shown in figure, find the V_{in}, V_s and power supplied by the dependent source



[CSE-2022 : 10 marks]

Solution:



By KCL at Node *X*;

$$-2 - 8 + i_X = 0$$

$$i_X = 10 \text{ A} \quad \text{...(i)}$$

$$V_d = 4i_X = 40 \text{ V}$$

Power supplied by dependent source = 40 × 10 = 400 W

By Ohm's law,

$$V_X = 3i_X - V_s \quad \text{...(ii)}$$

$$V_X = 4i_X - 8X^2 \quad \text{...(iii)}$$

$$V_X = 60 + V_{in} - 5X^2 \quad \text{...(iv)}$$

By (iii), $V_X = 40 - 16 = 24$ V

Using (i) and (iii) in (ii), $V_s = 3i_X - V_X = 6$ V

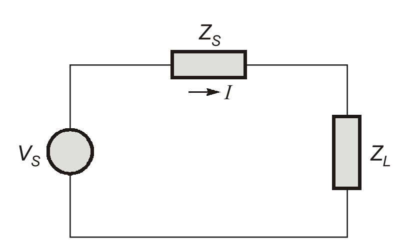
Using (i) and (iii) in (iv), $V_{in} = -26$ V

2. Network Theorems

2.1 If an impedance Z_L is connected across a voltage source V_s with source impedance Z_S, then for maximum power transfer, what will be the load impedance?

[CSE-2004 : 4 marks]

Solution:



$$Z_S = R + jX$$

$$Z_L = R_L + jX_L$$

$$I = \frac{V_S}{Z_S + Z_L}$$

Power transferred, $P = |I|^2 \cdot R_L$

$$P = \frac{V^2 \cdot R_L}{(R + R_L)^2 + (X + X_L)^2} \quad \text{...(1)}$$

For maximum power transfer, $\dfrac{\partial P}{\partial X_L} = 0$