$$\therefore v_{TH} = 20i_2 + 40i_1 = 100i_2 = 100 \times \frac{18}{65} \text{ Volt}$$

$$\therefore v_{TH} = \frac{360}{13} \text{ Volt.}$$

From Fig. 4.50(b),

$$R_{TH} = \left(40 \| 50 + 20\right) \| 30 = \frac{228}{13}\,\Omega$$

current through $10\,\Omega$ resistor,

$$i = \frac{v_{TH}}{R_{TH}+10} = \frac{360/13}{\left(\frac{228}{13}+10\right)} = \frac{360}{358} \text{ Amp.}$$

**EX- 4.20:** Obtain the current in $2\,\Omega$ resistor of the circuit shown in Fig. 4.51. Use Thevenin's theorem.

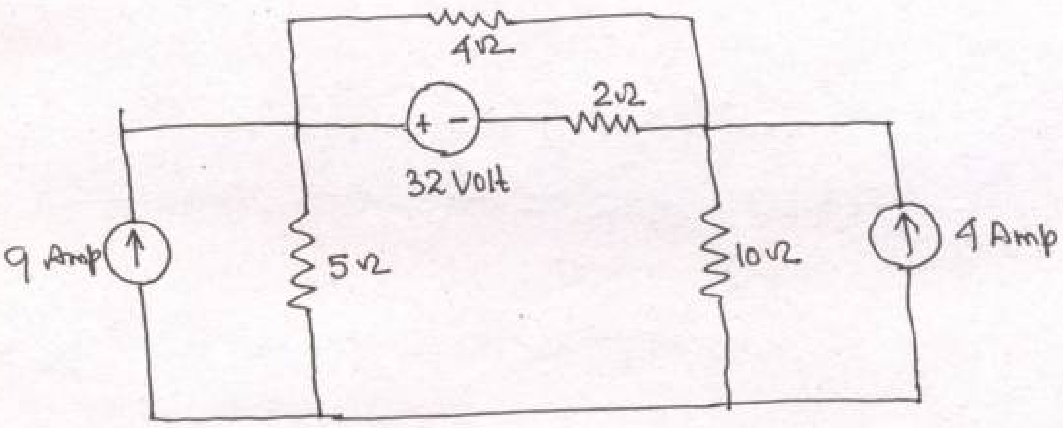



Fig. 4.51: Circuit for EX-4.20

**Soln.**

$2\,\Omega$ resistor is removed from Fig. 4.51 and the resulting circuit is shown in Fig. 4.52 to determine $v_{TH}$.

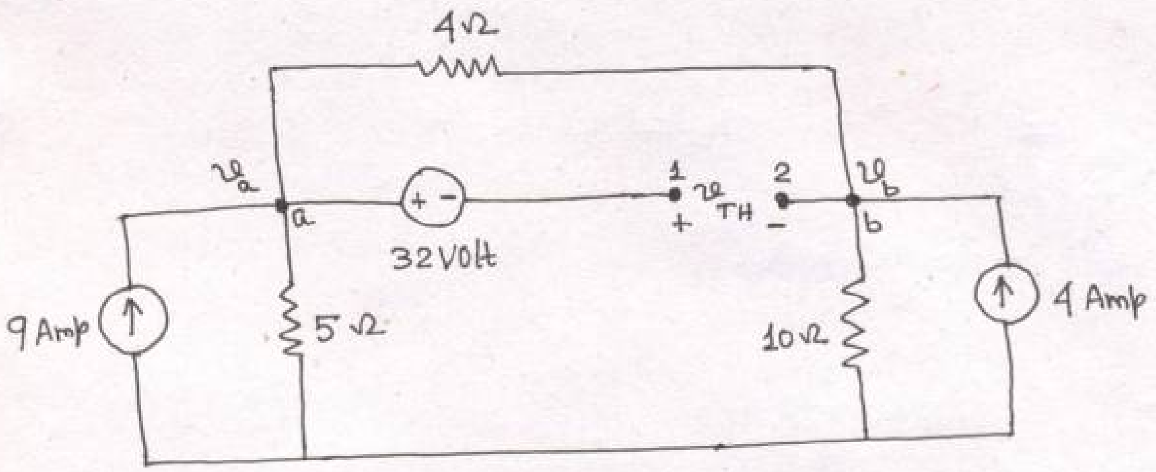



Fig. 4.52: Finding $v_{TH}$ for EX – 4.20

At ~~nd~~ node a,

$$\frac{v_a}{5} + \frac{v_a - v_b}{4} = 9 \quad \text{--- (i)}$$

At node b

$$\frac{v_a - v_b}{4} + 4 = \frac{v_b}{10} \quad \text{--- (ii)}$$

Solving eqns. (i) and (ii), we get,

$$v_a = \frac{830}{19} \text{ Volt} \; ; \; v_b = \frac{810}{19} \text{ Volt.}$$

Thus,

$$v_a - v_b - v_{TH} - 32 = 0$$

$$\therefore \; v_{TH} = \frac{830}{19} - \frac{810}{19} - 32 = -30.947 \text{ Volt.}$$

For determing $R_{TH}$, resulting circuit is shown in Fig. 4.53.

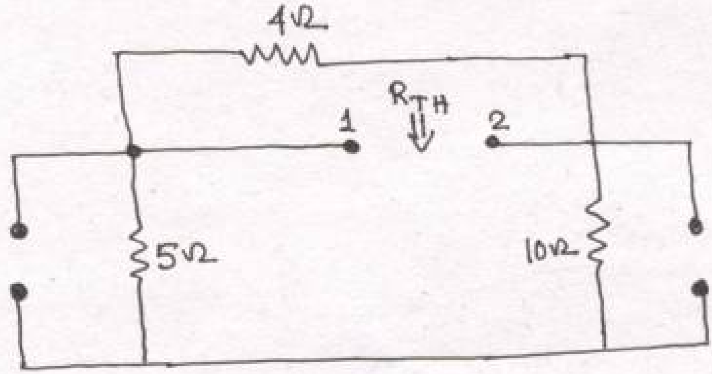



Fig. 4.53: Finding $R_{TH}$ for EX – 4.20

From Fig. 4.53, we have,

$$R_{TH} = \frac{(10+5)\times 4}{(10+5)+4} = \frac{60}{19}\ \Omega$$

Thevenin equivalent circuit is shown in Fig. 4.54

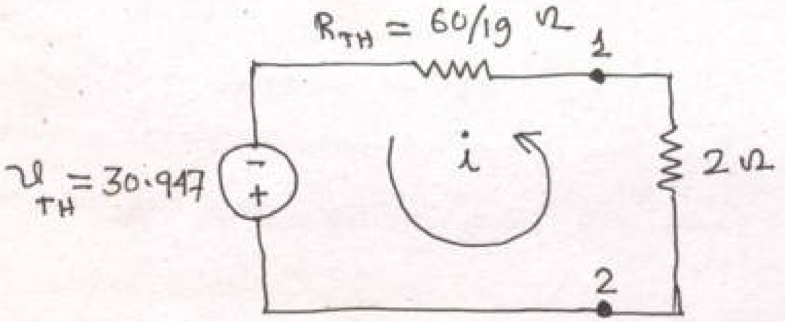
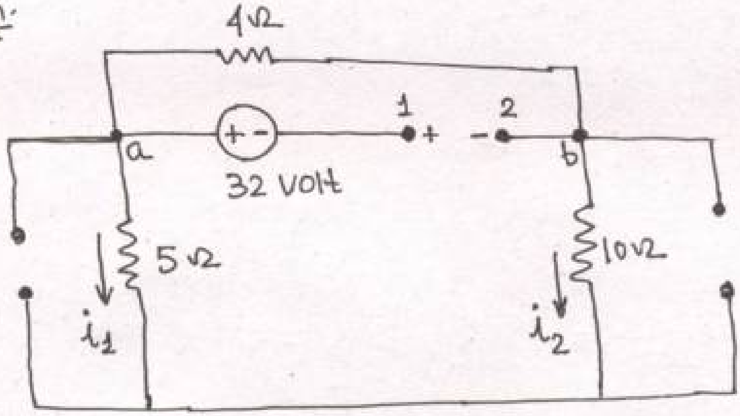



Fig. 4.54: Thevenin equivalent circuit for EX-4.20

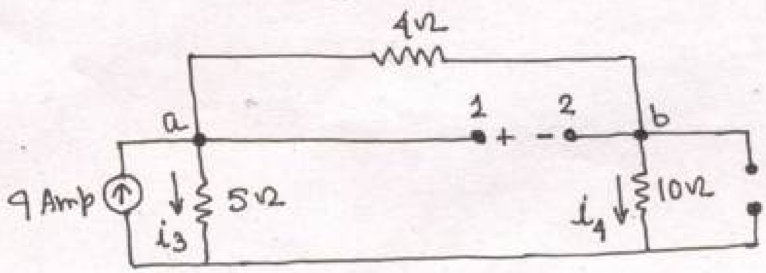
$$\therefore\ i = \frac{v_{TH}}{R_{TH}+2} = \frac{30.947}{\left(\frac{60}{19}+2\right)} = 6\ \text{Amp.}$$

EX-4.21 : Obtain the Thevenin voltage shown in the circuit of Fig. 4.51 - for EX-4.20

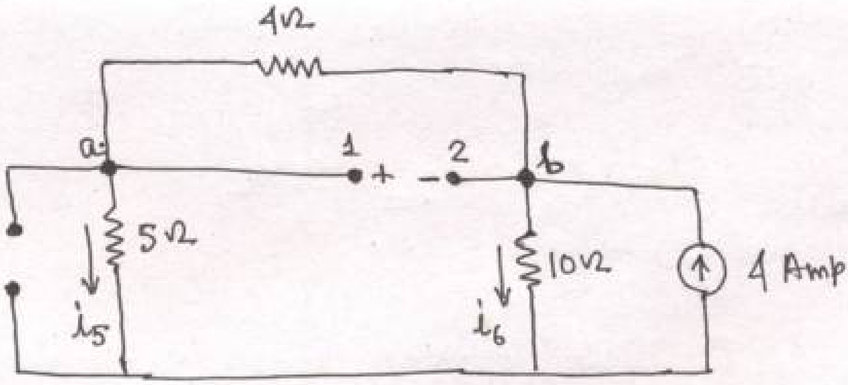
Soln.




(a)




(b)




(c)

Fig. 4.55: (a) Two independent current sources are turned off
(b) Voltage source and 4 Amp current sources are turned off
(c) Voltage source and 9 Amp current source are turned off.

~~Fig. 4.5~~ Fig. 4.55 gives three different circuits for obtaining $v_{TH}$ using superposition theorem.

From Fig. 4.55(a),

$$i_1 = 0.0; \quad i_2 = 0.0$$

From Fig. 4.55(b),

$$i_3 = \left(\frac{10+4}{10+4+5}\right) \times 9 = 6.63 \text{ Amp}; \quad i_4 = 9 - i_3 = 9 - 6.63 = 2.37 \text{ Amp}$$

From Fig. 4.55(c),

$$i_5 = \frac{10}{(10+5+4)} \times 4 = 2.11 \text{ Amp}; \quad i_6 = 4 - 2.11 = 1.89 \text{ Amp}$$

$$\therefore \quad i_{5\Omega} = i_1 + i_3 + i_5 = 0 + 6.63 + 2.11 = 8.74 \text{ Amp}$$

$$i_{10\Omega} = i_2 + i_4 + i_6 = 0 + 2.37 + 1.89 = 4.26 \text{ Amp}$$

$$\therefore \quad v_a = 5 \times i_{5\Omega} = 5 \times 8.74 = 43.7 \text{ Volt}$$

$$v_b = 10 \times i_{10\Omega} = 10 \times 4.26 = 42.6 \text{ Volt}$$

Thus

$$v_{TH} = v_a - v_b - 32 = 43.7 - 42.6 - 32 = -30.9 \text{ Volt.}$$

## 4.5: NORTON'S THEOREM

Norton's theorem states that a linear two terminal circuit can be replaced by an equivalent circuit consisting of a current source $i_N$ in parallel with a resistor $R_N$.

where,

$i_N$ = short circuit current through the terminals

$R_N$ = input or equivalent resistance at the terminals when the independent sources are turned off.

Consider the circuit given in Fig. 4.56(a). This circuit can be replaced by the one given in Fig. 4.56(b). We find $R_N$ in the same way we find $R_{TH}$. In fact, Thevenin and Norton resistances are equal, that is

$$R_N = R_{TH} \quad \text{- - - -} \quad (4.9)$$

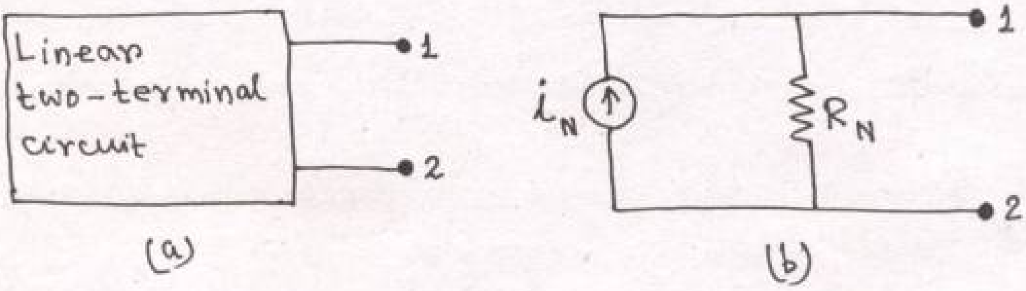



Fig. 4.56: (a) Original circuit (b) Norton equivalent circuit.

To determine the Norton current $i_N$, first compute the short circuit current flowing from terminal 1 to 2 in both circuits in Fig. 4.56

It is evident that the short circuit current in Fig. 4.56(b) is $i_N$ and this must be the same short circuit current from terminal 1 to 2 in Fig. 4.56(a). Since the circuits of Fig. 4.56(a) and Fig. 4.56(b) are equivalent, thus,

$$i_N = i_{sc} \quad --- \quad (4.10)$$

Fig. 4.57 shows the circuit for finding Norton current $i_N$.

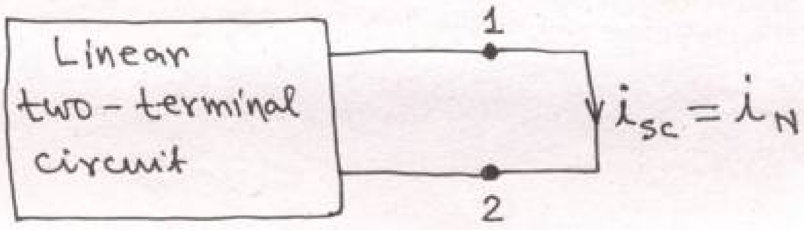



Fig. 4.57: Finding Norton current $i_N$

Also

$$i_N = \frac{v_{TH}}{R_{TH}} \quad ----- \quad (4.11)$$

Note that dependent and independent sources are treated the same way as in Thevenin's theorem.

The Thevenin and Norton equivalent circuits are related by a source transformation. For this reason, source transformation is often called Thevenin - Norton transformation.

To determine the Thevenin or Norton equivalent circuits require that we find:

1. The open circuit voltage $v_{oc}$ across terminals 1 and 2.

2. The short circuit current $i_{sc}$ at terminals 1 and 2.

3. The equivalent or input resistance $R_{in}$ at terminals 1 and 2 when all independent sources are turned off.

We summarize the relationships:

$$v_{TH} = v_{oc} \quad \cdots \quad (4.12)$$

$$i_N = i_{sc} \quad \cdots \quad (4.13)$$

$$R_{TH} = \frac{v_{oc}}{i_{sc}} = R_N \quad \cdots \quad (4.14)$$

Open circuit and short circuit tests are sufficient to find any Thevenin or Norton equivalent.

Ex-4.22: Determine Norton equivalent circuit of the circuit shown in Fig. 4.58

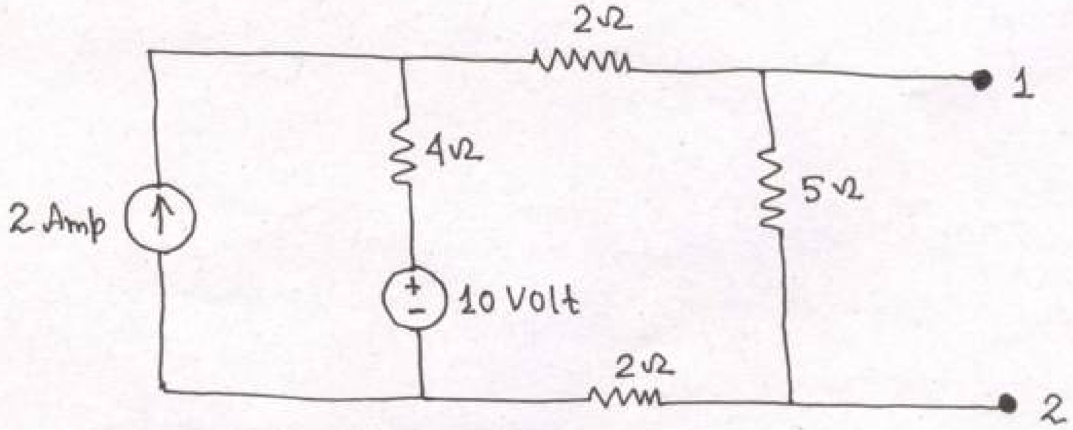
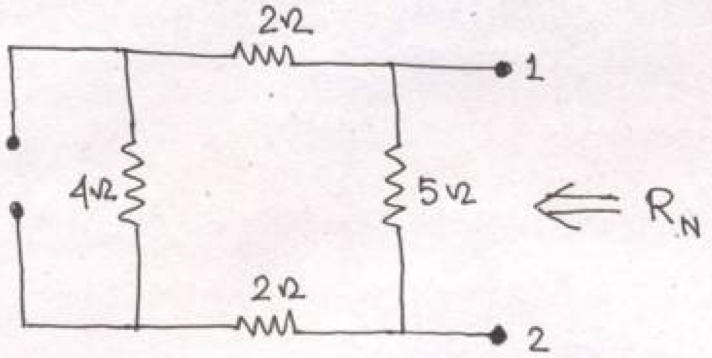


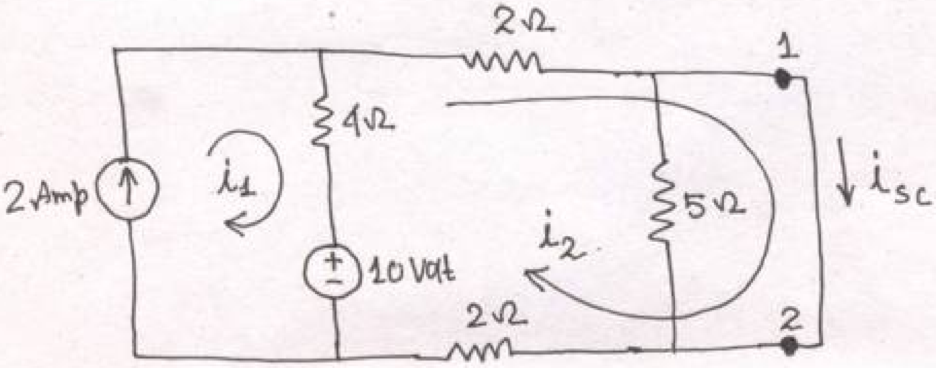

Fig. 4.58: Circuit for Ex-4.22.

Soln.

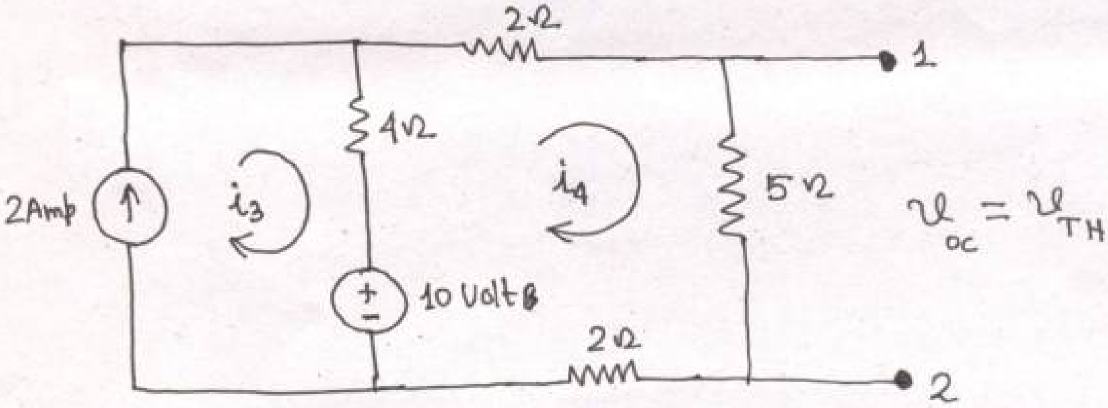





(a)




(b)




(c)

Fig. 4.59: (a) finding $R_N$ (b) finding $i_N = i_{sc}$
(c) finding $v_{oc} = v_{TH}$

We determine $R_N$ in the same way we find $R_{TH}$ in the Thevenin equivalent circuit. All the independent sources are turned off and this leads to the circuit in Fig. 4.59(a). Thus

$$R_N = \frac{5 \times (2+4+2)}{5 + (2+4+2)} = 3.077\Omega = R_{TH}$$

To determine $i_N$, terminals 1 and 2 are short circuited as shown in Fig. 4.59(b). 5 Ω resistor is ignored because it has been short circuited.

Applying mesh analysis, we get,

$$i_1 = 2\text{ Amp} \quad \text{and} \quad 8i_2 - 4i_1 = 10$$

$$\therefore 8i_2 = 4\times 2 + 10 \qquad \therefore i_2 = 2.25\text{ Amp.}$$

$$\therefore i_{sc} = i_2 = 2.25\text{ Amp.}$$

Alternatively, we can determine $i_N = v_{TH}/R_{TH}$.

We obtain $v_{TH}$ as the open circuit voltage across terminals 1 and 2 in Fig. 4.59(c). Using mesh analysis, we obtain,

$$i_3 = 2\text{ Amp;}$$

$$13i_4 - 4i_3 = 10 \qquad \therefore 13i_4 = 4\times 2 + 10$$

$$\therefore i_4 = 1.384\text{ Amp.}$$

$$\therefore v_{TH} = v_{oc} = 5i_4 = 5\times 1.384 = 6.923\text{ Volt.}$$

Hence,

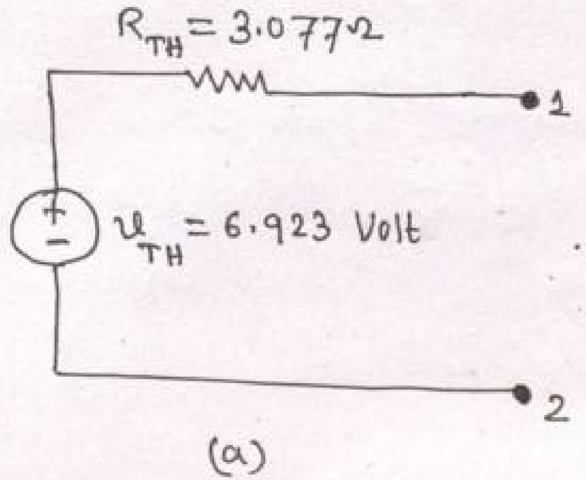
$$i_N = \frac{v_{TH}}{R_{TH}} = \frac{6.923}{3.077} = 2.25\text{ Amp}$$

as obtained previously.

This also serves to confirm eqn (4.14), that

$$R_{TH} = R_N = \frac{v_{oc}}{i_{sc}} = \frac{6.923}{2.25} = 3.077\,\Omega.$$

Thevenin and Norton equivalent circuits are shown in Fig. 4.60(a) and Fig. 4.60(b) respectively.



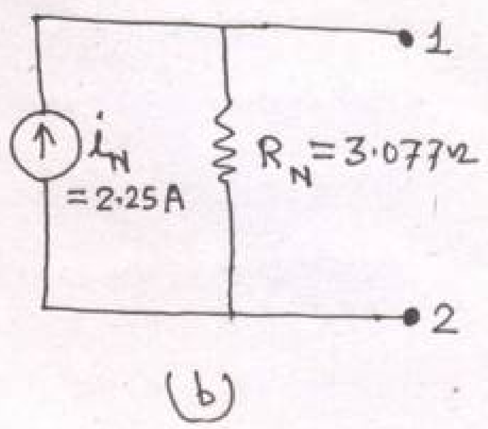




Fig.4.60: (a) Thevenin equivalent circuit
(b) Norton equivalent circuit.

**EX-4.23:** Using Norton's theorem, determine $R_N$ and $I_N$ of the circuit shown in Fig.4.61.

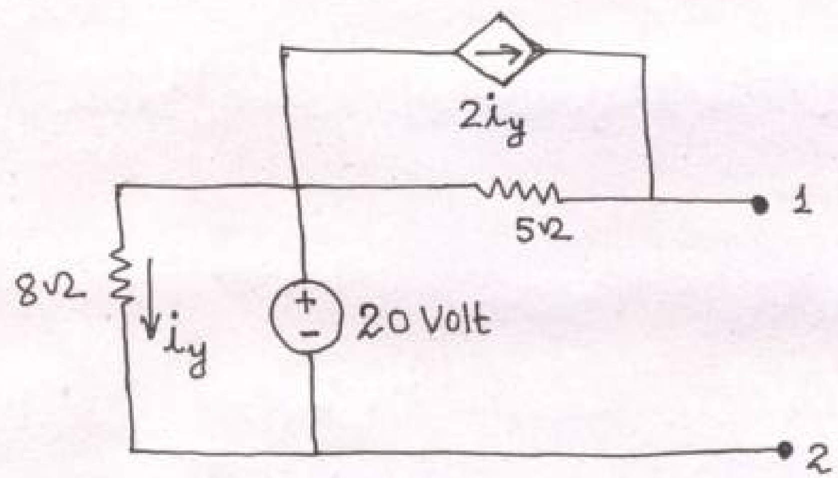



Fig. 4.61: Circuit for EX-4.23

Soln.

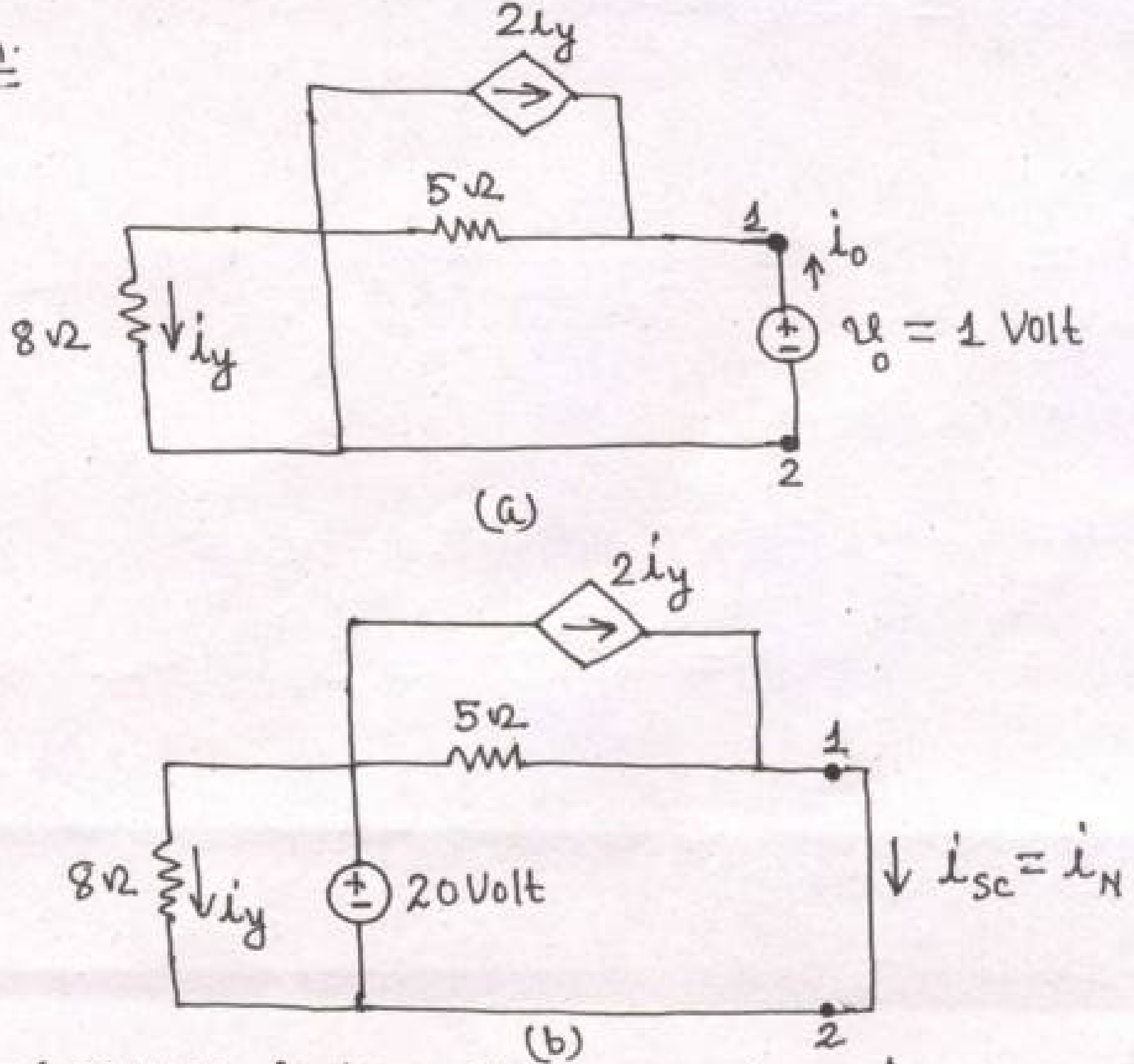



Fig. 4.62: (a) finding $R_N$ (b) finding $i_N$

To find $R_N$, we turned off the independent voltage source and connect a voltage source of $v_o = 1$ Volt to the terminals 1 and 2 and resulting circuit is shown in Fig. 4.62(a). We ignore the 8 Ω resistance of Fig. 4.62(a) because it is short circuited. Also due to the short circuit, the dependent current source, 5 Ω resistor and independent voltage source are in parallel.

Hence, $i_y = 0.0$. ~~At node 1~~, $i_o =$

At node 1,

$$i_o = \frac{v_o}{5} = \frac{1}{5} \text{ Amp.}$$

and

$$R_N = \frac{v_o}{i_o} = \frac{1}{(1/5)} = 5\,\Omega.$$

To determine $i_N$, terminals 1 and 2 are short circuited and the resulting circuit is shown in Fig. 4.62(b). In Fig. 4.62(b), dependent current source, 5 Ω resistor, 20 Volt and 8 Ω resistor all are in parallel. Hence,

$$i_y = \frac{20}{8} = 2.5 \text{ Amp;}$$

At node 1, KCL gives

$$i_{sc} = \frac{20}{5} + 2i_y = 4 + 2\times 2.5 = 9 \text{ Amp.}$$

Thus,

$$i_N = i_{sc} = 9 \text{ Amp.}$$

**EX-4.24:** Determine the current in 10 Ω resistor of the circuit shown in Fig. 4.63 by Norton's theorem.

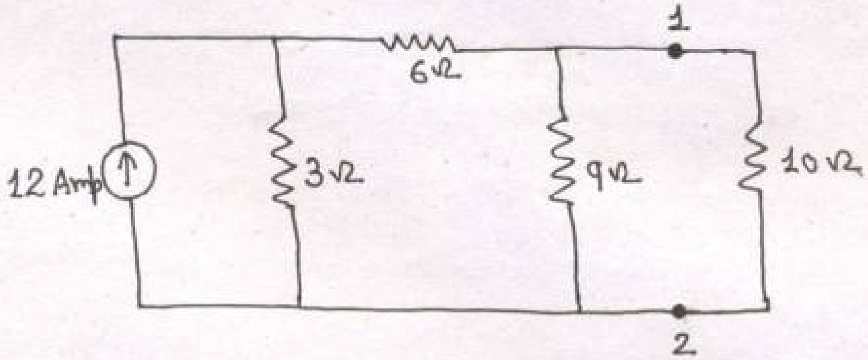
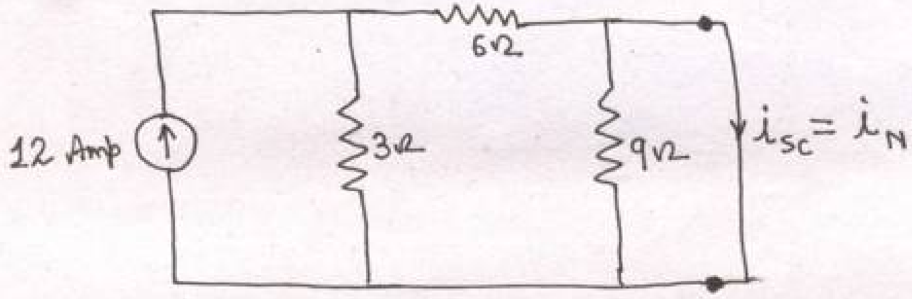
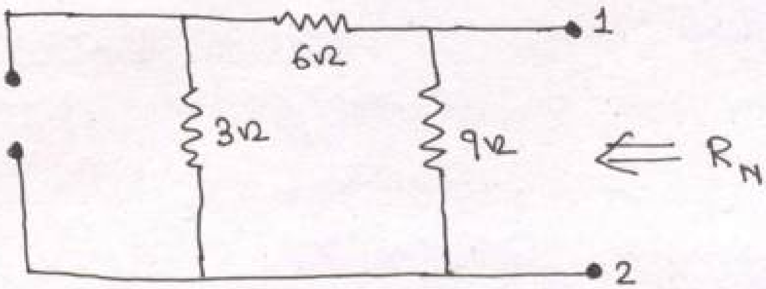



Fig.4.63: Circuit for Ex-4.24

Soln.




(a)




(b)

Fig.4.64: (a) finding $i_N$ (b) finding $R_N$

In Fig.4.64(a), 9 Ω resistor is short circuited. Hence,

$$i_N = \frac{3}{(3+6)} \times 12 = 4 \text{ Amp}$$

From Fig. 4.64(b),

$$R_N = \frac{9 \times (6+3)}{9 + (6+3)} = 4.5\Omega$$

Fig. 4.65 shows Norton equivalent circuit.

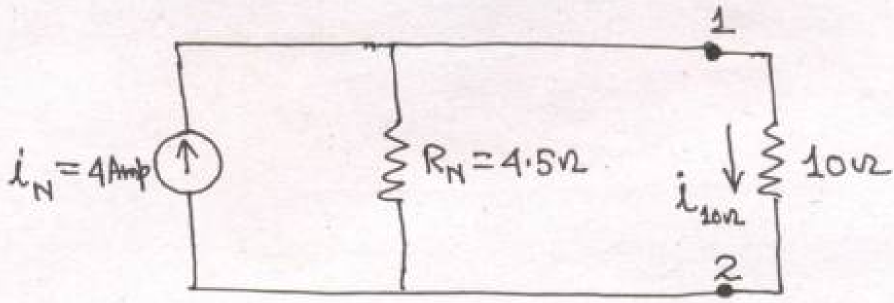



Fig. 4.65: Norton Equivalent circuit for EX-4.24.

Current through $10\ \Omega$ resistor is given by

$$i_{10\Omega} = \frac{4.5}{(4.5+10)} \times 4 = 1.241 \text{ Amp.}$$

EX-4.25: Obtain the Norton equivalent circuit for the circuit shown in Fig. 4.66 to determine the current in the $50\Omega$ resistor.

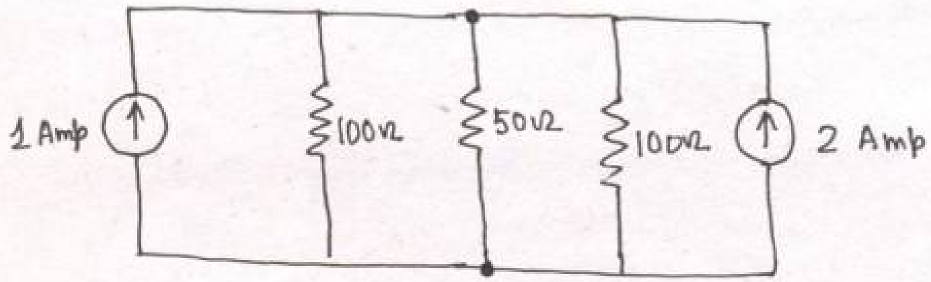
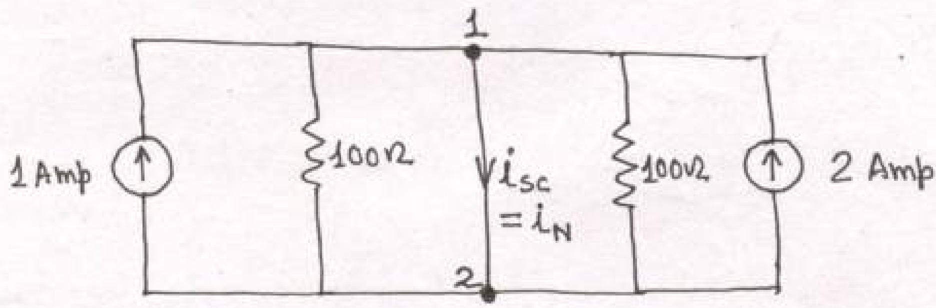
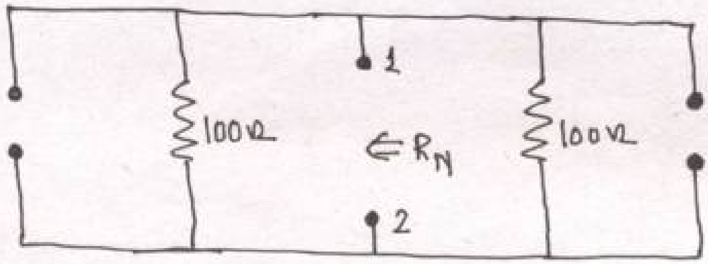



Fig. 4.66: Circuit for EX-4.25

Soln.




(a)




(b)

Fig. 4.67: (a) finding $i_N$ (b) finding $R_N$

In Fig. 4.67(a), both 100Ω resistors are short circuited. Hence,

$$i_{sc} = i_N = 1 + 2 = 3 \text{ Amp}$$

In Fig. 4.67(b), Both 100Ω resistors are in parallel, hence,

$$R_N = \frac{100 \times 100}{100 + 100} = 50\Omega$$

Norton equivalent circuit is given in Fig. 4.68

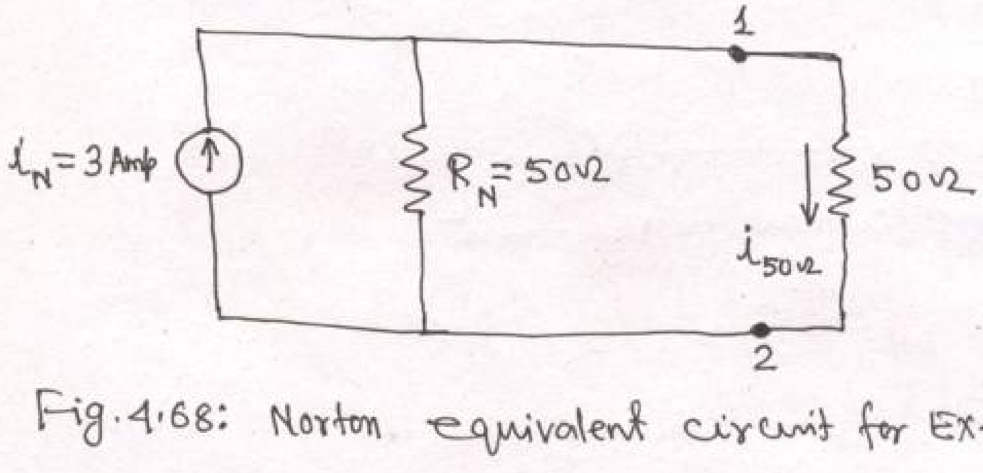



Fig. 4.68: Norton equivalent circuit for EX-4.25

$$\therefore \; i_{50\Omega} = 3 \times \frac{50}{50+50} = 1.5 \text{ Amp.}$$

EX-4.26: Obtain Norton equivalent circuit of the circuit shown in Fig. 4.69.

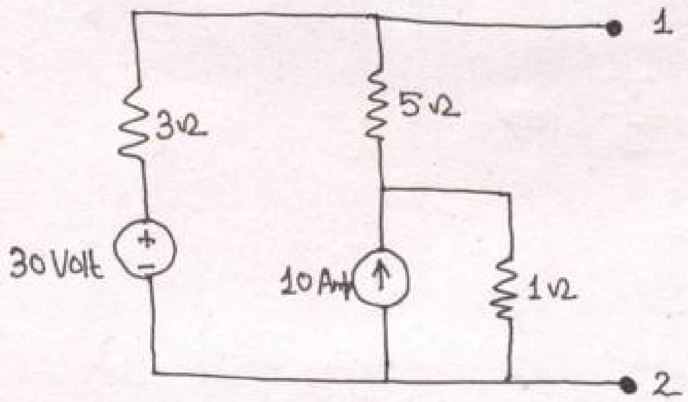
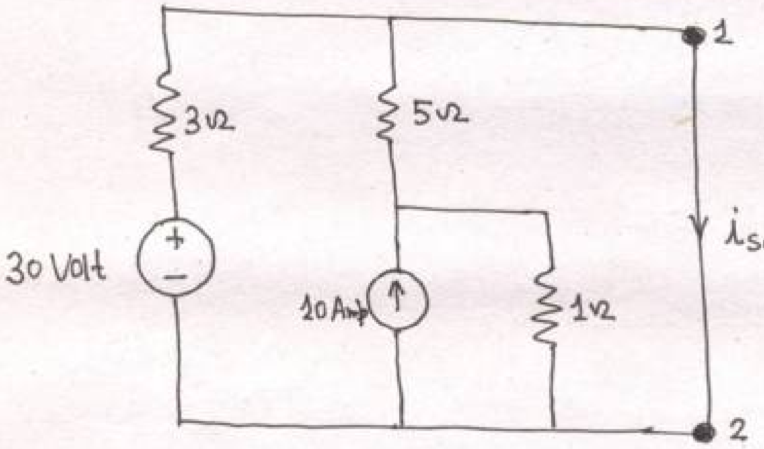
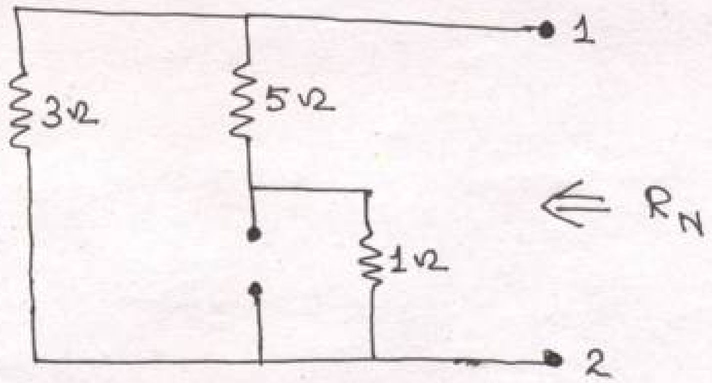



Fig. 4.69: Circuit for Ex-4.26

Soln.




(a)




(b)

Fig. 4.70: (a) finding $i_N$ (b) finding $R_N$

In Fig. 4.70(a), short circuit current is given by

$$i_{sc} = \left(\frac{30}{3}\right) + \frac{1}{(5+1)} \times 10$$

$$\therefore i_{sc} = 10 + \frac{5}{3} = \frac{35}{3} \text{ Amp}$$

$$\therefore i_N = i_{sc} = \frac{35}{3} \text{ Amp.}$$

From Fig. 4.70(b),

$$R_N = \frac{3 \times (5+1)}{3+(5+1)} = 2\Omega$$

Norton equivalent circuit is given in Fig. 4.71.

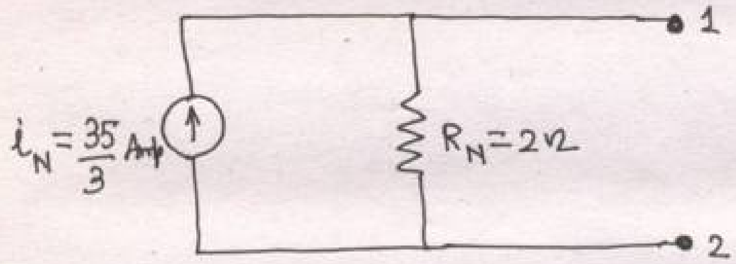



Fig. 4.71: Norton equivalent circuit for Ex-4.26

<u>Ex-4.27:</u> Determine $R_N$ of the circuit shown in Fig. 4.72 using $R_N = v_{oc}/i_{sc}$.

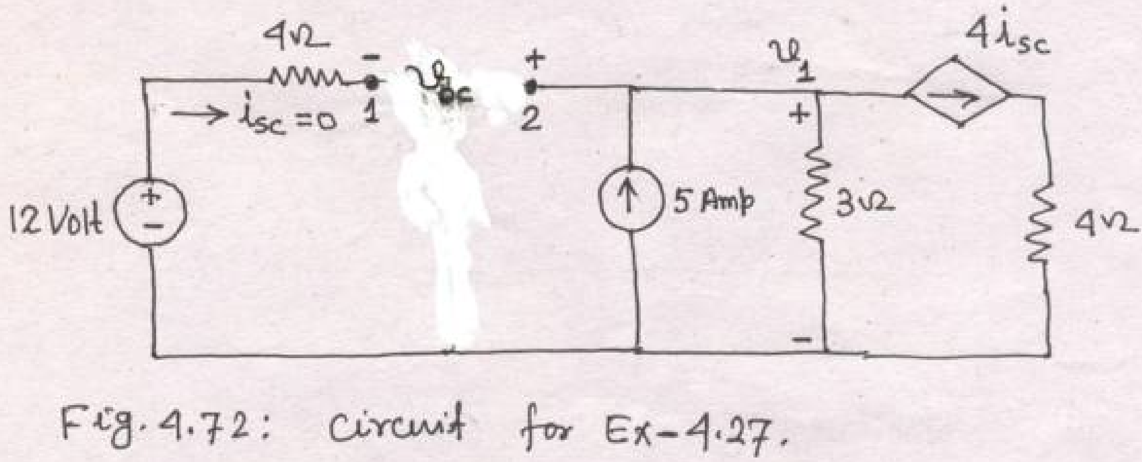



Fig. 4.72: Circuit for Ex-4.27.

<u>Soln.</u>

In the circuit of Fig. 4.72, $i_{sc} = 0$, hence,

$v_1 = 5 \times 3 = 15$ Volt.

Thus,

$$v_1 - 12 - v_{oc} = 0$$

$$\therefore v_{oc} = 15 - 12 = 3 \text{ Volt.}$$

To determine $i_{sc}$, terminals 1 and 2 are short circuited and the resulting circuit is shown in Fig. 4.73.

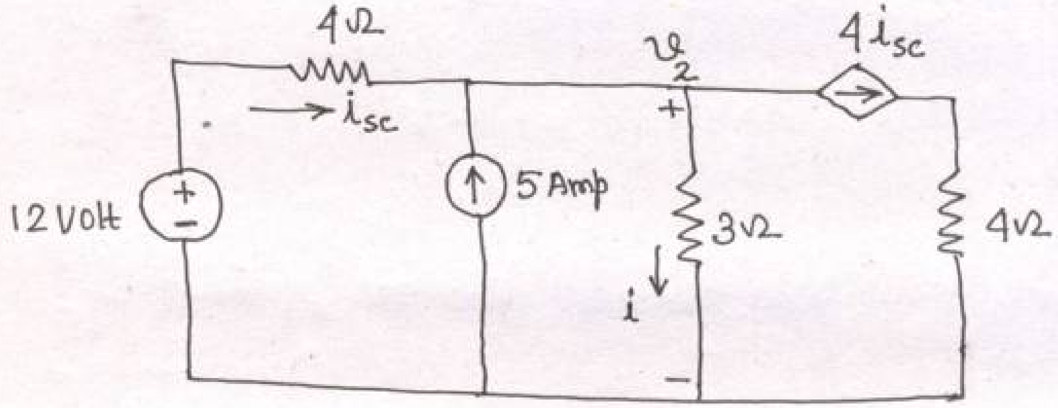



Fig. 4.73: finding $i_{sc}$ for Ex-4.27

$$i_{sc} = \frac{12 - v_2}{4}, \quad i = \frac{v_2}{3}$$

Applying nodal analysis

$$\frac{12 - v_2}{4} + 5 = \frac{v_2}{3} + 4 \cdot \left(\frac{12 - v_2}{4}\right)$$

$$\therefore v_2 = 9.6 \text{ Volt.}$$

$$\therefore i_{sc} = \frac{12 - v_2}{4} = \frac{12 - 9.6}{4} = 0.6 \text{ Amp.}$$

$$\therefore R_N = \frac{v_{oc}}{i_{sc}} = \frac{3}{0.6} = 5\,\Omega$$

**Ex-4.28:** Obtain the Thevenin equivalent circuit at the terminals 1-2 of the circuit shown in Fig. 4.74 (62)

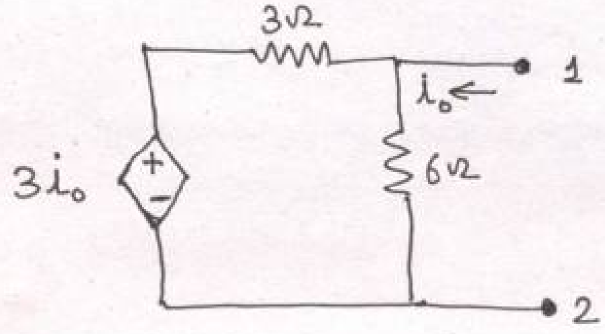



Fig. 4.74: Circuit for Ex-4.28

Soln.

Note that the circuit does not contain any independent source. To obtain the Thevenin equivalent, a voltage source of 1 Volt is applied across the terminals 1-2 and the resulting circuit is shown in Fig. 4.75.

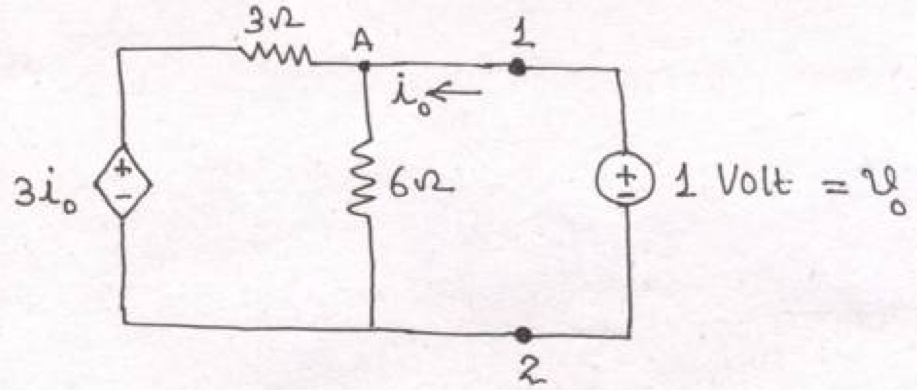



Fig. 4.75: finding $R_{TH}$.

Using nodal analysis (At node A)

$$i_o = \frac{1}{6} + \frac{1-3i_o}{3} \quad \therefore \; i_o = \frac{1}{4} \text{ Amp}$$

$$\therefore \; R_{TH} = \frac{v_o}{i_o} = \frac{1}{1/4} = 4\,\Omega$$

Note that there is no independent source in Fig. 4.74, hence, $v_{TH} = 0$. The Thevenin equivalent circuit is shown in Fig. 4.76.

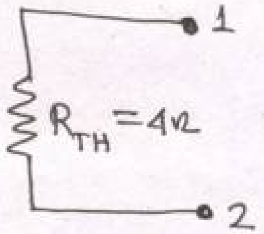



Fig. 4.76: Thevenin equivalent circuit for EX-4.28

## 4.6: MAXIMUM POWER TRANSFER

In many practical cases, a circuit is designed to provide power to a load. There are applications in many areas where it is desirable to maximize the power delivered to the load.

The Thevenin equivalent is useful in finding the maximum power, a linear circuit can deliver to a load. We assume that load resistance $R_L$ is adjustable. If the entire circuit is replaced by its Thevenin equivalent except for the adjustable load resistance as shown in Fig. 4.77, the power delivered to the load is

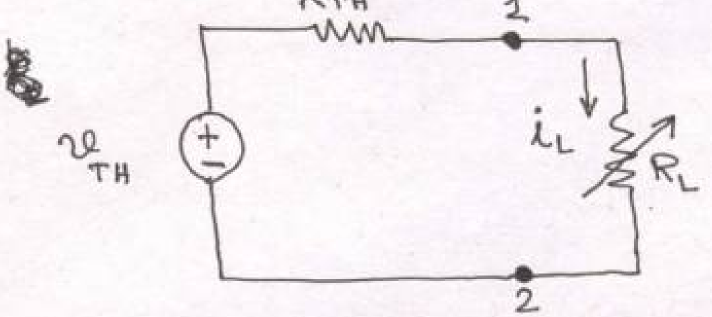



Fig. 4.77: The circuit used for maximum power transfer.

$$p_L = i_L^2 R_L = \left(\frac{v_{TH}}{R_{TH} + R_L}\right)^2 R_L \quad \text{----} \quad (4.15)$$

For a given circuit, $v_{TH}$ and $R_{TH}$ are fixed. By varying $R_L$, the power delivered to the load can be varied and it is sketched in Fig. 4.78

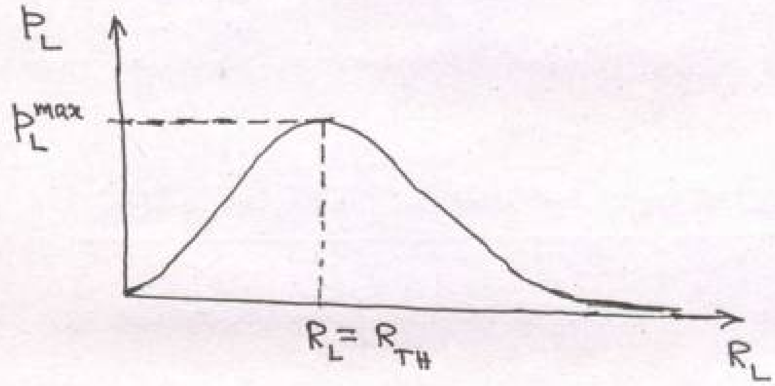



Fig. 4.78: $p_L$ as a function of $R_L$

From Fig. 4.78, we notice that $p_L$ is small for small or large value of $R_L$ but maximum for some value $R_L$ between 0 and $\infty$.

To determine the condition for maximum power transfer, we set,

$$\frac{dp_L}{dR_L} = 0 \quad \text{-----} \quad (4.16)$$

$$\therefore \quad v_{TH}^2 \left[\frac{(R_{TH} + R_L)^2 - 2R_L(R_{TH} + R_L)}{(R_{TH} + R_L)^4}\right] = 0$$

$$\therefore \quad R_{TH} + R_L - 2R_L = 0$$

$$\therefore \quad R_L = R_{TH} \quad \text{-----} \quad (4.17)$$

Therefore, maximum power occurs when $R_L = R_{TH}$. This is known as maximum power theorem.

Substituting $R_L = R_{TH}$, in eqn.(4.15), we get,

$$p_L^{max} = \frac{v_{TH}^2}{4R_{TH}} \quad \text{-------- (4.18)}$$

Ex-4.29: Determine the value of $R_L$ for maximum power transfer in the circuit shown in Fig. 4.79. Also find the maximum power.

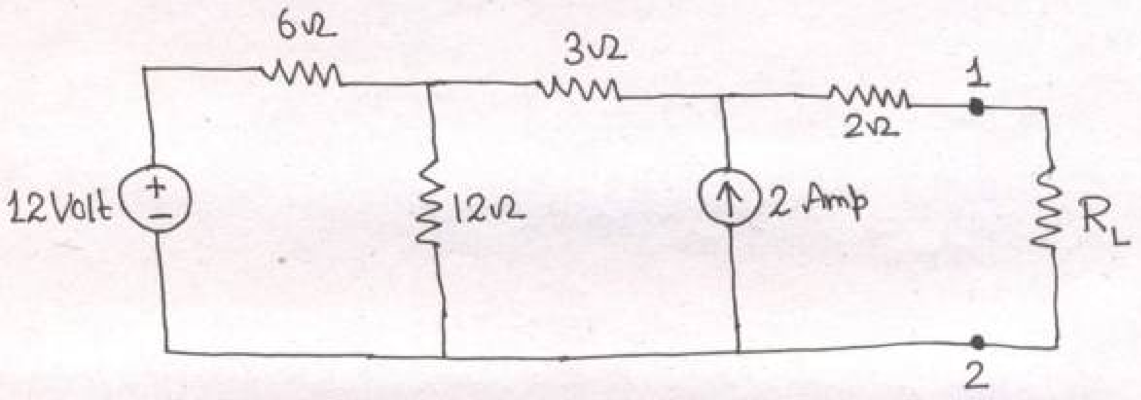



Fig. 4.79: Circuit for Ex-4.29

Soln.

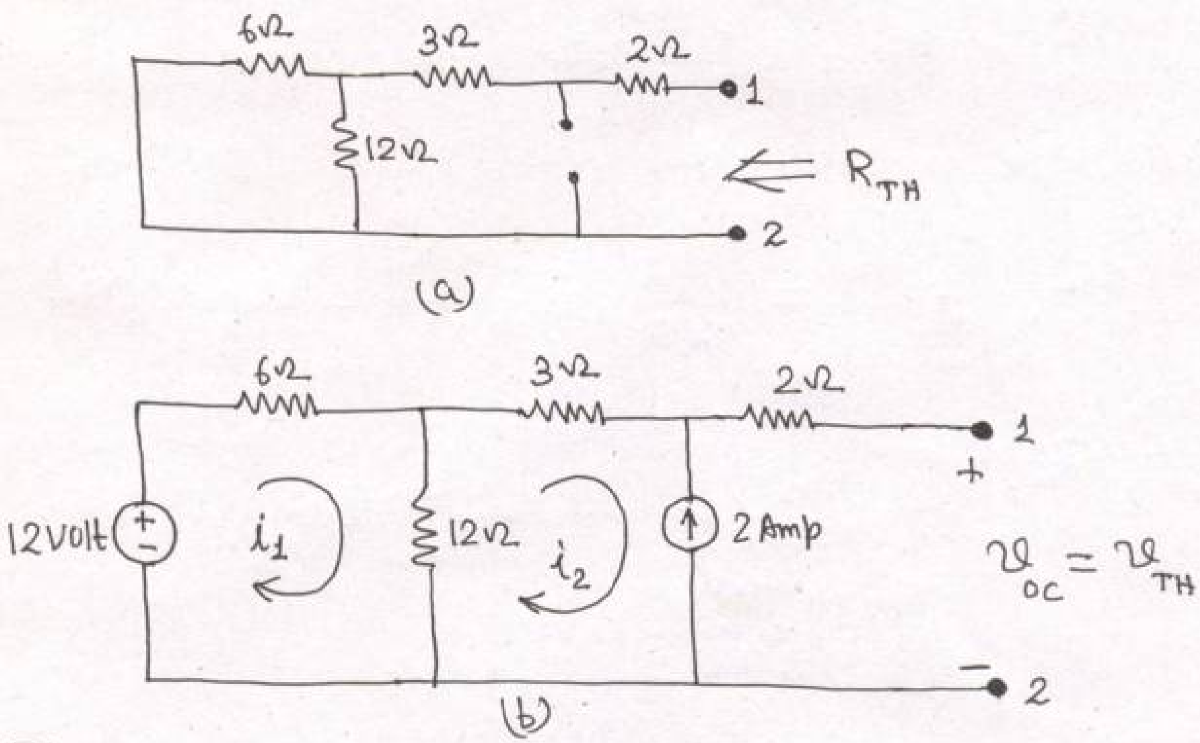



Fig. 4.80: (a) finding $R_{TH}$ (b) finding $v_{TH}$.

We need to determine $R_{TH}$ and $v_{TH}$. From Fig. 4.80(a), 66

$$R_{TH} = (2+3) + \frac{6\times12}{6+12} = 9\Omega$$

From Fig. 4.80(b), we obtain by mesh analysis,

$$i_2 = -2 \text{ Amp}$$

and

$$18i_1 = 12 + 12i_2 = 12 + 12(-2) = -12$$

$$\therefore i_1 = -\frac{2}{3} \text{ Amp.}$$

Thus

$$3i_2 + v_{TH} + 12(i_2 - i_1) = 0$$

$$\therefore v_{TH} = -3i_2 - 12(i_2 - i_1)$$

$$\therefore v_{TH} = -3(-2) - 12\left(-2 + \frac{2}{3}\right)$$

$$\therefore v_{TH} = 22 \text{ Volt}$$

For maximum power transfer,

$$R_L = R_{TH} = 9\Omega$$

and the maximum power is,

$$p_L^{max} = \frac{v_{TH}^2}{4R_L} = \frac{(22)^2}{4\times9} = 13.44 \text{ Watt.}$$

Ex-4.30: In the circuit of Fig. 4.81, what resistor $R_L$ will absorb maximum power and what is this power?

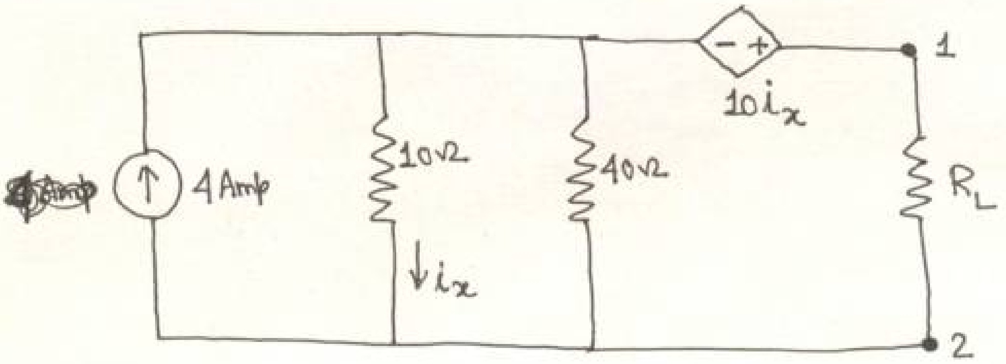



Fig. 4.81: Circuit for EX- 4.30

Soln.

For maximum power transfer,

$$R_L = R_{TH} \quad \text{and} \quad p_L^{max} = v_{TH}^2 / (4R_{TH})$$

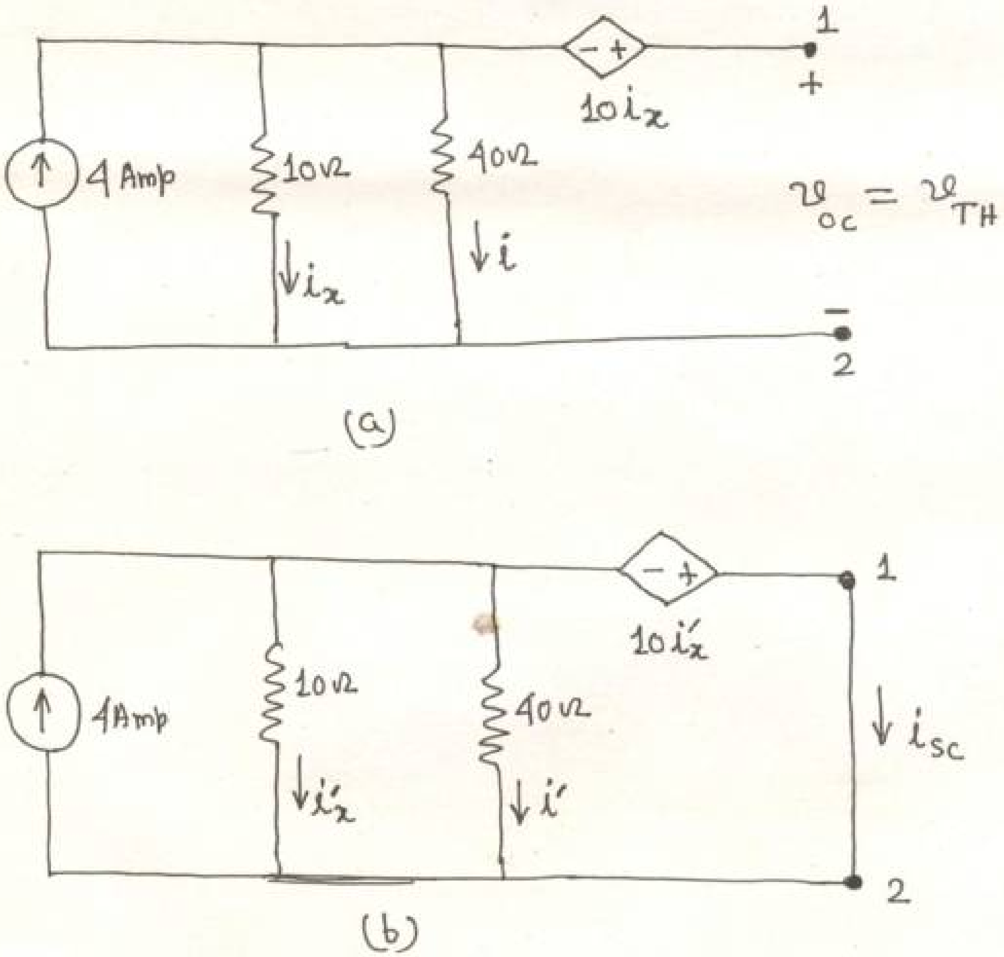



Fig. 4.82: (a) finding $v_{TH}$ (b) finding $i_{sc}$

In Fig. 4.82(a),

$$i_x = \frac{40}{(40+10)} \times 4 = 3.2 \text{ Amp}$$

$$\therefore \; i = 4 - 3.2 = 0.8 \text{ Amp}$$

Thus

$$10 i_x + 40 i - v_{TH} = 0$$

$$\therefore \; v_{TH} = 40 \times 0.8 + 10 \times 3.2 = 64 \text{ Volt.}$$

It is convenient to use the short circuit current approach to determine $R_{TH}$. In Fig. 4.82(b), terminals 1-2 are short circuited. Hence ~~and~~ $40\Omega$ and $10\Omega$ resistors are short circuited. ~~and~~ No current will be flowing through $10\Omega$ and $40\Omega$ resistors. Thus $i_x' = 0.0$ and $i' = 0.0$. Therefore all 4 Amp current will flow through the short circuit.

$$\therefore \; i_{sc} = 4 \text{ Amp.}$$

$$\therefore \; R_{TH} = \frac{v_{TH}}{i_{sc}} = \frac{64}{4} = 16\Omega$$

Thus, $R_L = R_{TH} = 16\Omega$

$$\therefore \; p_L^{max} = \frac{v_{TH}^2}{4R_{TH}} = \frac{(64)^2}{4 \times 16} = 64 \text{ Watt.}$$

**Ex-4.31:** In the circuit of Fig.4.83, find $R_L$ for maximum power transfer and also determine $P_L^{max}$.

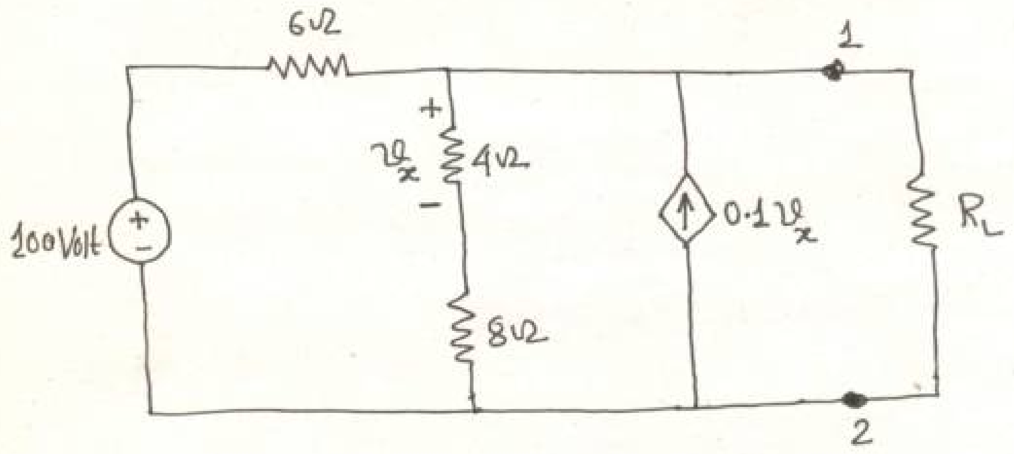



Fig. 4.82: Circuit for Ex-4.31

**Soln.**

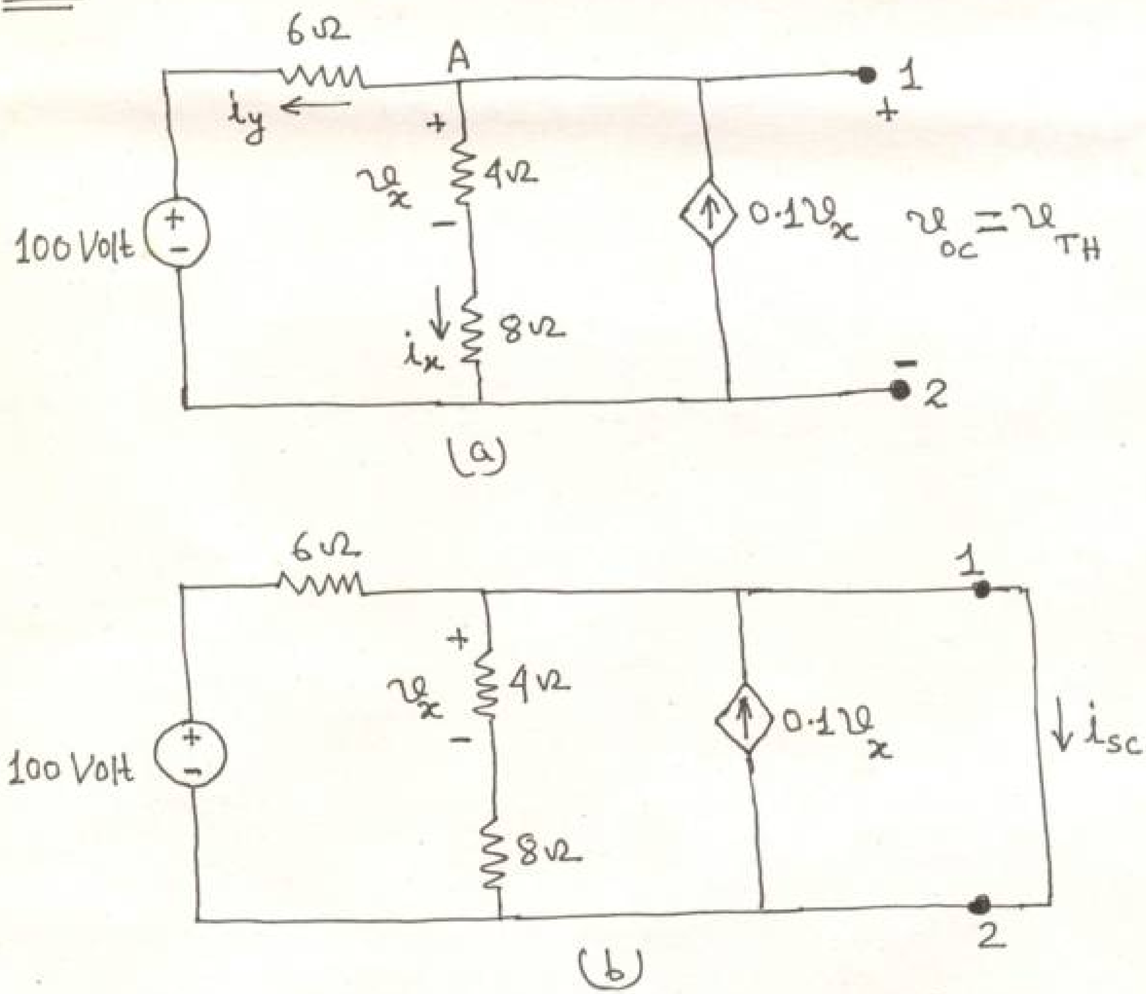



Fig.4.83: (a) finding $v_{TH}$ (b) finding $i_{sc}$

In Fig.4.83(a), load resistance $R_L$ is removed and $v_{oc} = v_{TH}$. Now $4\Omega$ resistor is in series with $8\Omega$ resistor. Voltage across $4\Omega$ resistor is $v_x$,

$$\therefore \quad v_x = 4i_x \quad \text{---(i)}$$

Applying KVL, we get,

$$v_{TH} = 4i_x + 8i_x$$

$$\therefore v_{TH} = 12i_x \quad \text{----(ii)}$$

From eqns.(ii) and (i), we have

$$v_{TH} = 3v_x \quad \text{---(iii)}$$

At node A,

$$\frac{3v_x - 100}{6} + \frac{v_x}{4} - 0.1v_x = 0$$

$$\therefore \frac{v_x}{2} + \frac{v_x}{4} - 0.1v_x = \frac{100}{6}$$

$$\therefore v_x = 25.64 \text{ Volt}$$

$$\therefore v_{TH} = 3v_x = 3 \times 25.64 = 76.92 \text{ Volt.}$$

$$\therefore i_y = \frac{3v_x - 100}{6} = \frac{3 \times 25.64 - 100}{6} = -3.846 \text{ Amp}$$

$$i_x = \frac{v_x}{4} = \frac{25.64}{4} = 6.41 \text{ Amp}$$

In Fig.4.83(b), terminals 1-2 are short circuited to determine $i_{sc}$ and hence $R_{TH}$. As the terminals 1-2 are short circuited, $v_x = 0.0$, this means

$(4+12)\,\Omega = 12\,\Omega$ resistor is short circuited. 71

Thus

$$i_{sc} = \frac{100}{6} = \frac{50}{3} \text{ Amp}$$

$$\therefore\ R_{TH} = \frac{v_{TH}}{i_{sc}} = \frac{76.92}{(50/3)} = 4.615\ \Omega$$

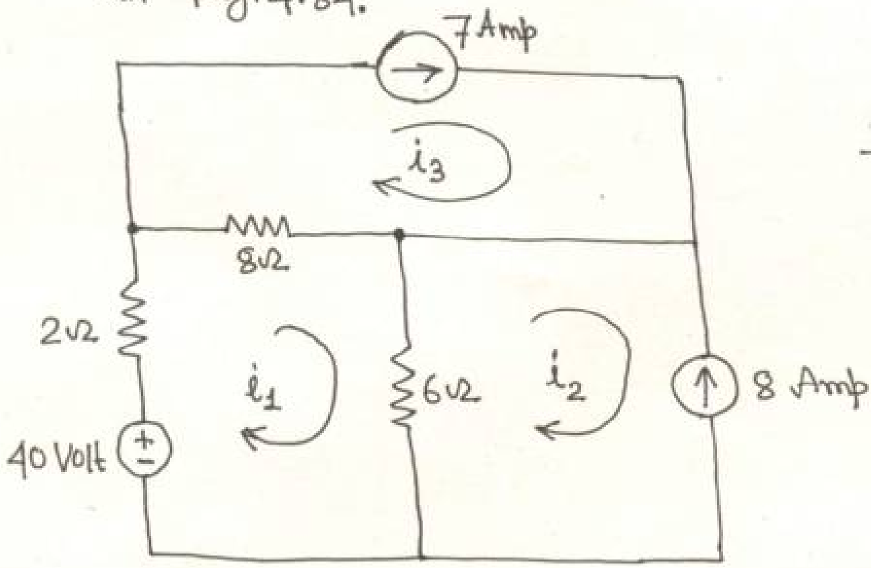
For maximum power transfer,

$$R_L = R_{TH} = 4.615\,\Omega$$

$$\therefore\ p_L^{max} = \frac{v_{TH}^2}{4R_{TH}} = \frac{(76.92)^2}{4 \times 4.615} = 320.51 \text{ Watt.}$$

## EXERCISE - 4

4.1: Determine $i_1$, $i_2$ and $i_3$ for the circuit shown in Fig. 4.84.



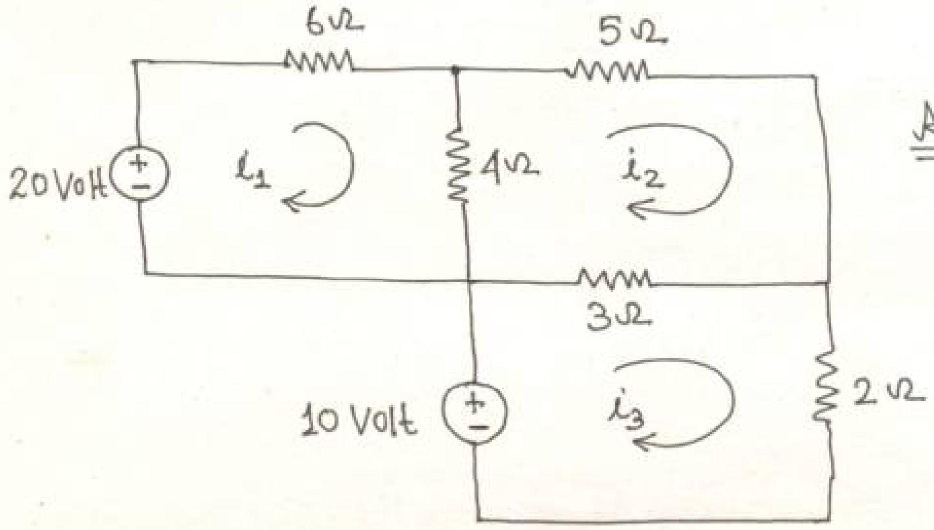

Ans: $i_1 = 3$ Amp

$i_2 = -8$ Amp

$i_3 = 7$ Amp.

Fig. 4.84: Circuit for Problem 4.1

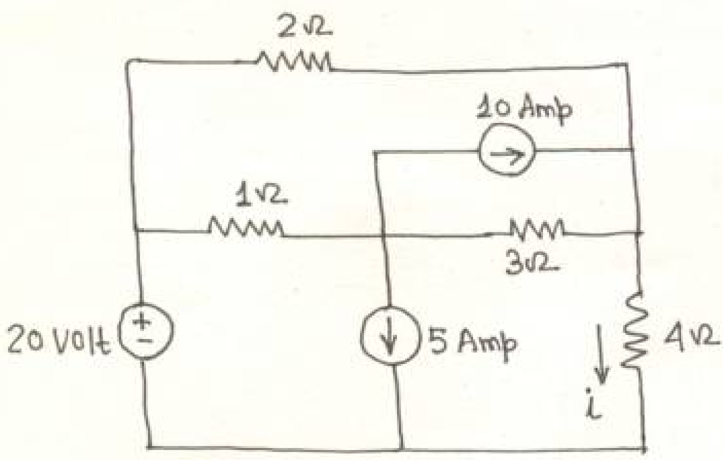
4.2: Determine current through 2 Ω resistor of the circuit shown in Fig. 4.85 by using superposition.




**Ans:** $i_3 = 2.98$ Amp

Fig. 4.85: Circuit for Problem 4.2

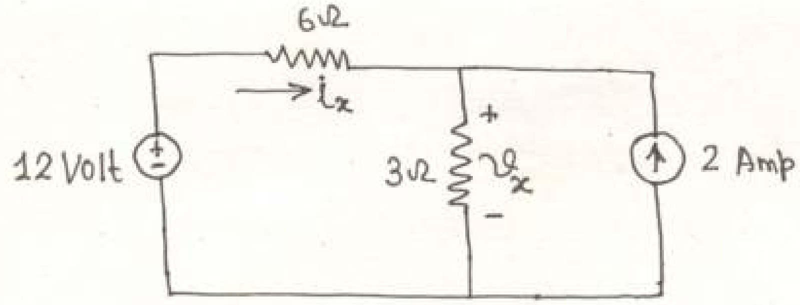
4.3: Calculate the current through 4 Ω resistor of the circuit shown in Fig. 4.86 by superposition.




**Ans:** $i = 5.31$ Amp

Fig. 4.86: Circuit for Problem 4.3

4.4: Determine $v_x$ and $i_x$ of the circuit shown in Fig. 4.87 by applying source transformation.

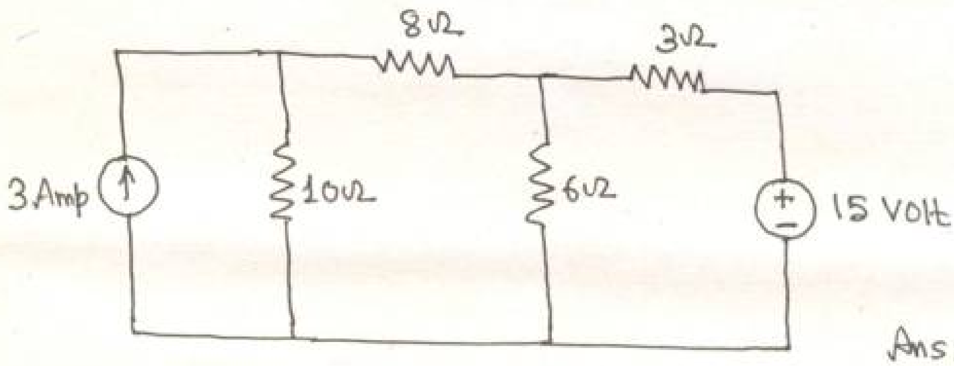



Ans: $v_x = 8$ Volt

$i_x = 0.67$ Amp

Fig. 4.87: Circuit for Problem 4.4

4.5: Using source transformation determine current and power in 8 Ω resistor of the circuit shown in Fig. 4.88




Ans: 1 Amp

8 Watt.

Fig. 4.88: Circuit for Problem 4.5

4.6: In the circuit of Fig. 4.89, determine $v_o$ using source transformation.

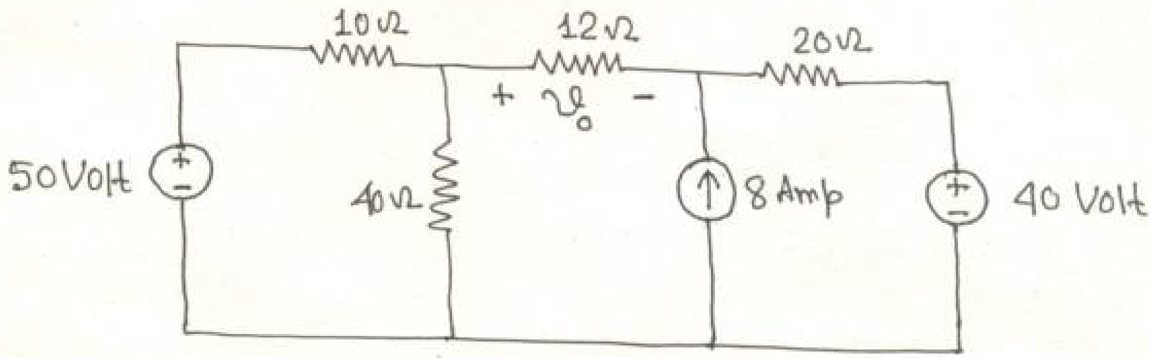



Fig. 4.89: Circuit for Problem 4.6

Ans: $v_o = -48$ Volt.

4.7: Determine the current $i_x$ in the circuit of Fig. 4.90 by making a succession of appropriate source transformations. Also find the power developed by the 75 Volt source.

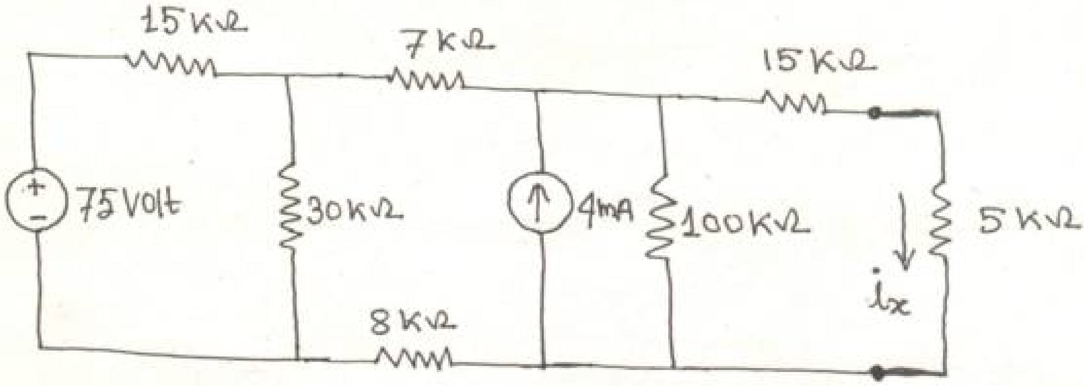



Fig. 4.90: Circuit for Problem 4.7

<u>Ans:</u> 3 mAmp

0.105 Watt

4.8: Find $v_o$ of the circuit of Fig. 4.91 by using source transformations. Also find (a) the power developed by the 300 Volt source (b) the power developed by 10 Amp current source (c) verify that the total power developed equals to the total power dissipated.

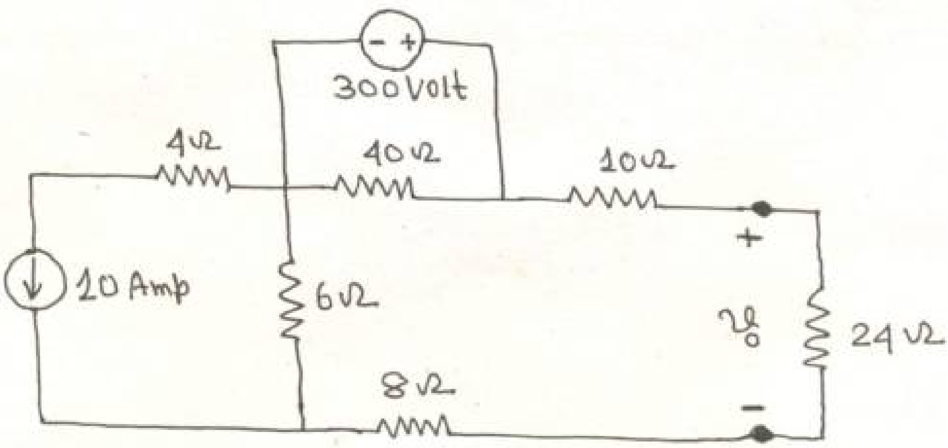



Fig. 4.91: Circuit for Problem 4.8

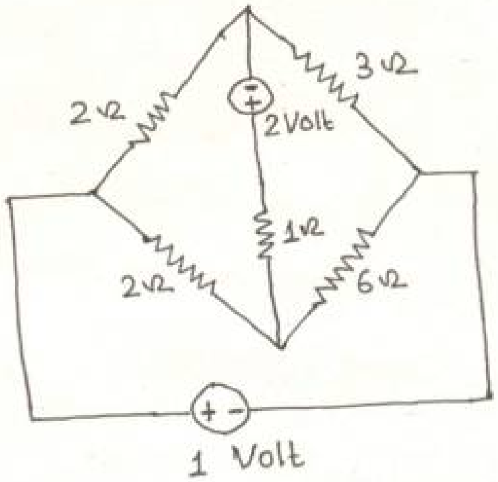
<u>Ans:</u> $v_o = 120$ Volt

(a) 3750 Watt

(b) 1300 Watt

(c) 5050 Watt

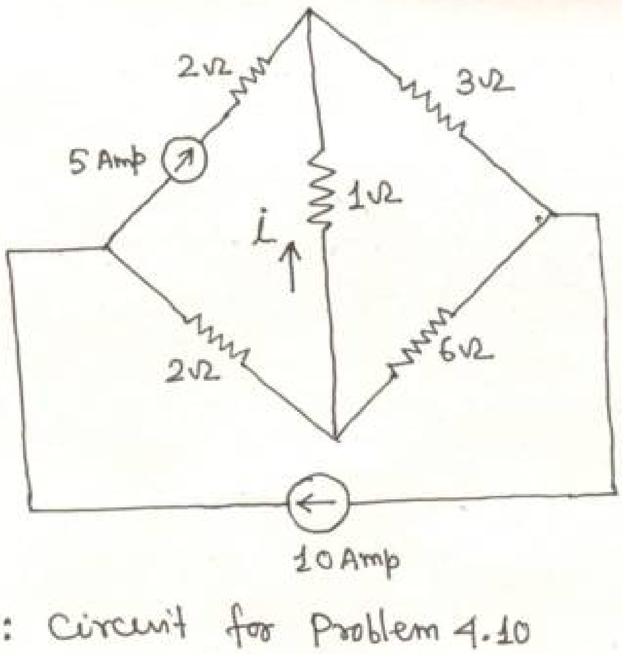
4.9: Determine the current through 3 Ω resistor of the circuit shown in Fig. 4.92 by using superposition.




Ans: 0.0 Amp

Fig. 4.92: Circuit for Problem 4.9

4.10: Determine the current through 1 Ω resistor of the circuit shown in Fig. 4.93 by using superposition.




Ans: $i = 1.5$ Amp

Fig. 4.93: Circuit for Problem 4.10

4.11: Determine $v_x$ of the circuit shown in Fig. 4.93 by using superposition.

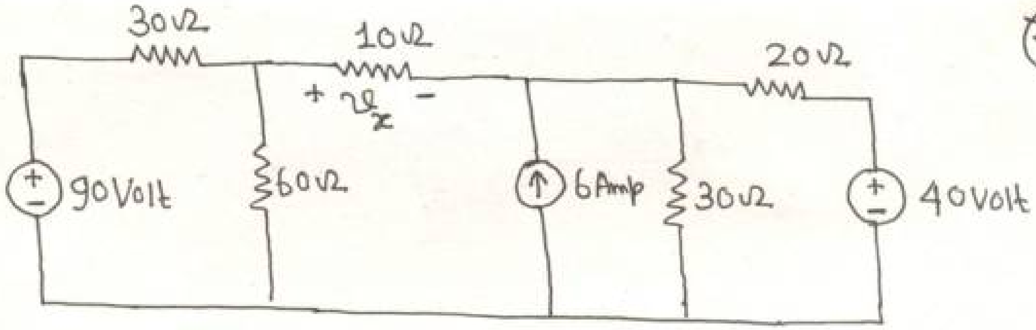



Fig.4.93: Circuit for Problem 4.11.

**Ans:** $v_x = -8.57$ Volt

4.12: Determine $v_o$ of the circuit shown in Fig.4.94 by using source transformation

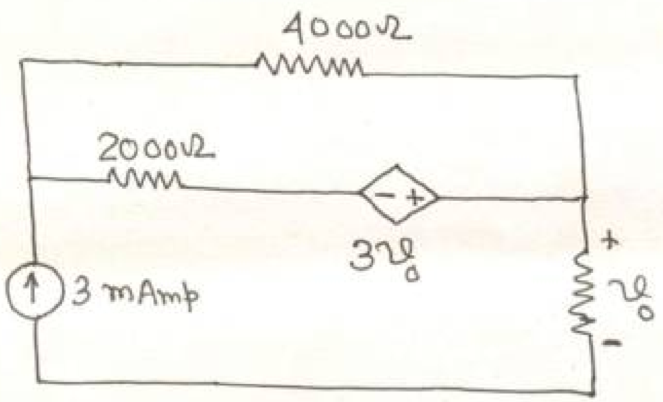



Fig.4.94: Circuit for Problem 4.12

**Ans:** $v_o = 3$ Volt

4.13: Determine the Thevenin equivalent circuit of which hold for the terminal pair 1-2 in the circuit of Fig.4.95

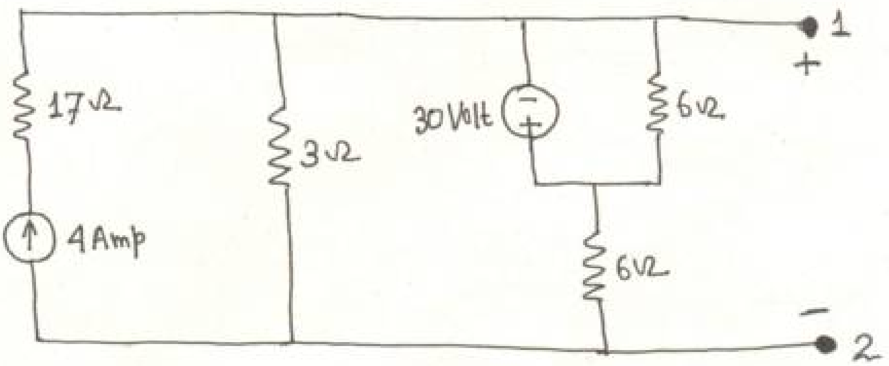
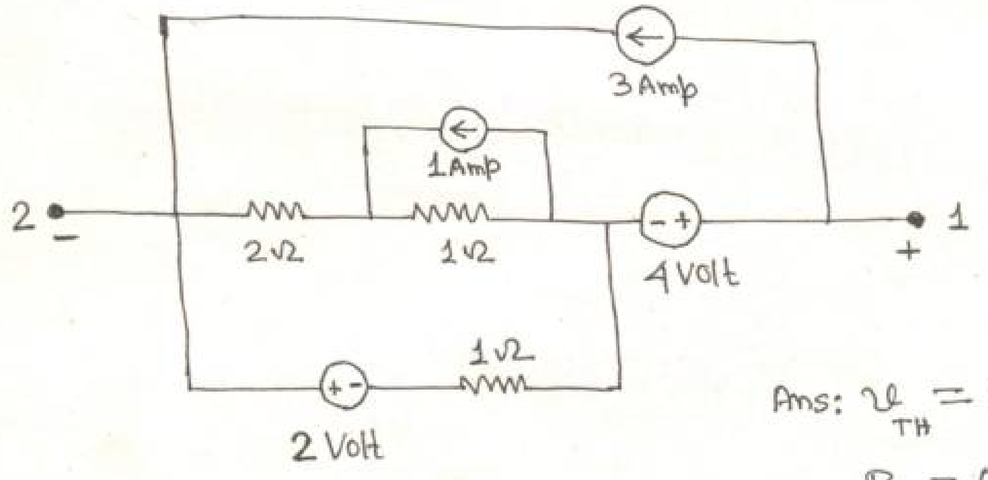



Fig.4.95: Circuit for Problem 4.13

Ans: $v_{TH} = -2$ Volts

$R_{TH} = 2Ω$

4.14: Determine the Thevenin equivalent circuit for the network shown in Fig. 4.96 at the terminals 1-2




Ans: $v_{TH} = 0.0$ Volt

$R_{TH} = 0.75\,\Omega$

Fig. 4.96: Circuit for Problem 4.14

4.15: Determine the Thevenin equivalent circuit of the network shown in Fig. 4.97 at the terminals 1-2.

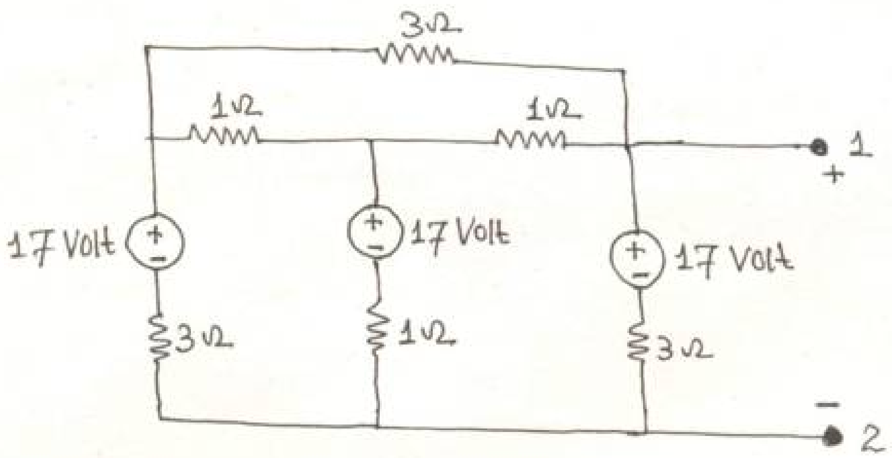



Fig. 4.97: Circuit for Problem 4.15

Ans: $v_{TH} = 17$ Volts

$R_{TH} = 1\,\Omega$

4.16: Determine the Thevenin equivalent circuit of the network shown in Fig. 4.98 at the terminals 1-2.

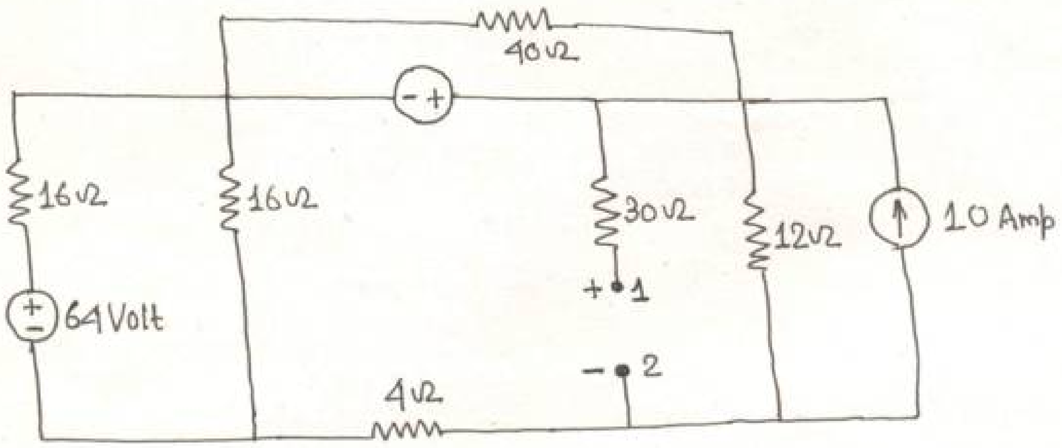



Fig. 4.98: Circuit for Problem 4.16

Ans: $v_{TH} = 88$ Volts

$R_{TH} = 36\Omega$

4.17: Determine the Norton equivalent circuit for the network shown in Fig. 4.99.

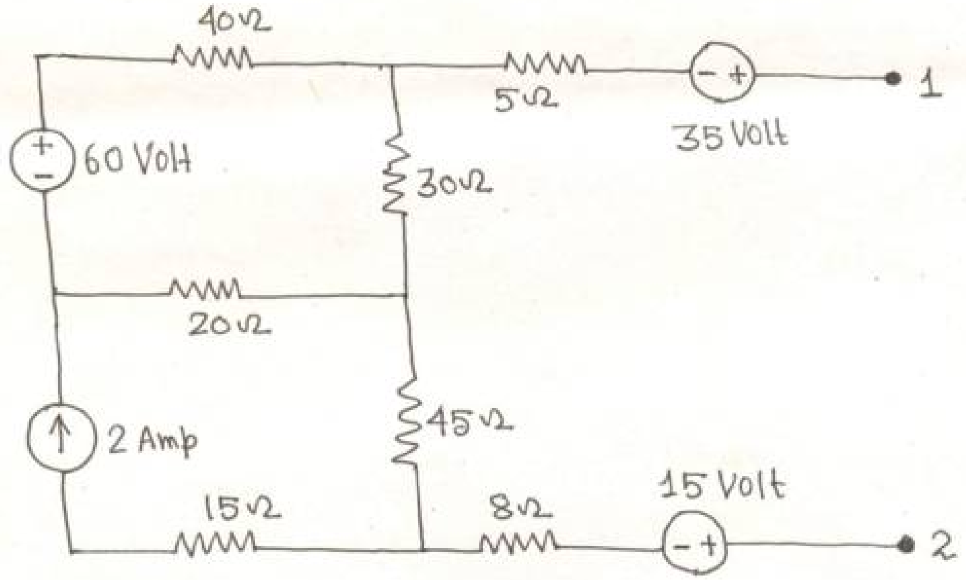
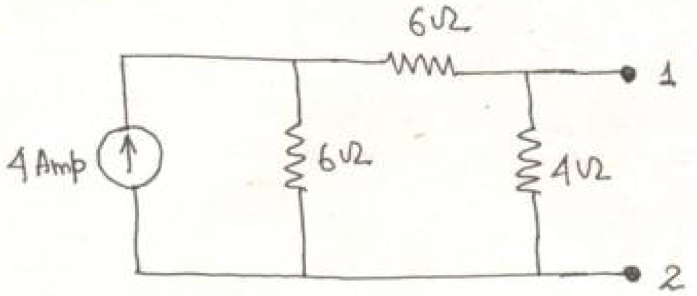



Fig. 4.99: Circuit for Problem 4.17

Ans: $i_N = 1.84$ Amp

$R_N = 78\Omega$.

4.18: Determine Norton equivalent of the circuit in Fig. 4.100 at the terminals 1–2.




Ans: $i_N = 2$ Amp
$R_N = 3\Omega$

Fig. 4.100: Circuit for Problem 4.18

4.19: Determine Norton equivalent of the circuit shown in Fig. 4.101 at the terminals 1-2.

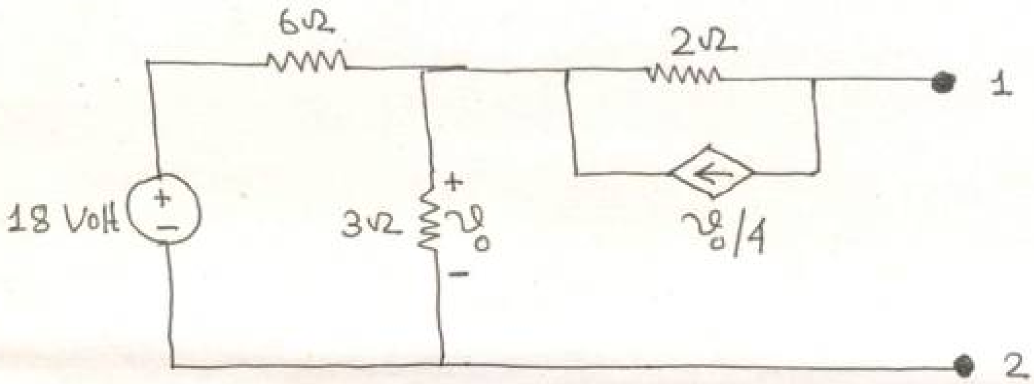
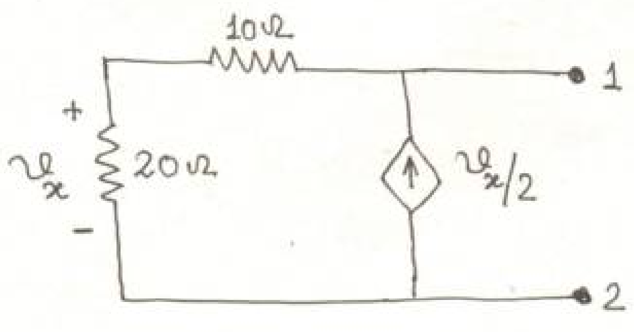



Fig. 4.101: Circuit for Problem 4.19

Ans: $i_N = 1$ Amp
$R_N = 3\Omega$

4.20: Determine the Norton equivalent for the circuit shown in Fig. 4.102




Ans: $i_N = 0.0$ Amp
$R_N = -\frac{1}{3}\Omega$

Fig. 4.102: Circuit for Problem 4.20

4.21: Determine the value of $R_L$ for which it draws maximum power in the circuit of Fig. 103. Also determine $p_L^{max}$.

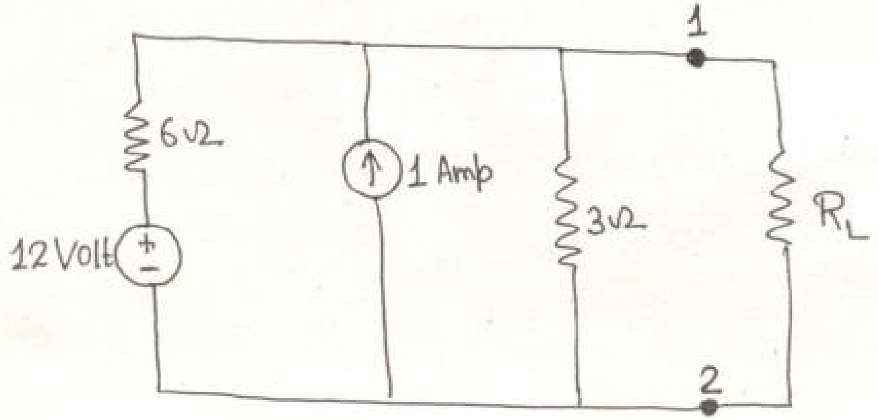



Fig. 4.103: Circuit for Problem 4.21

Ans: $R_L = 2\Omega$

$p_L^{max} = 4.5$ Watt.

4.22: Determine the value of $R_L$ for which it absorbs maximum power in the circuit of Fig. 4.104 and also determine $p_L^{max}$.

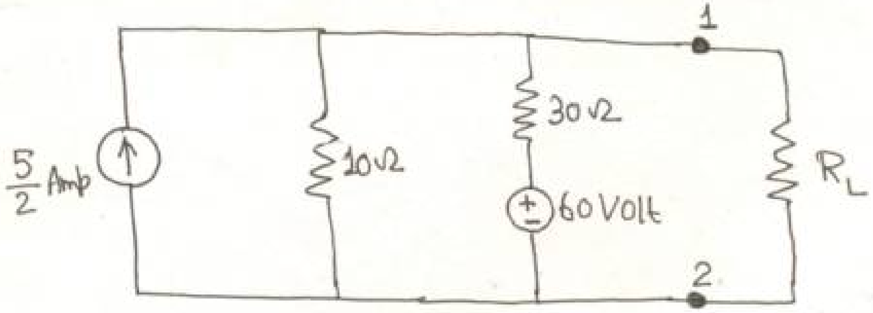



Fig. 4.104: Circuit for Problem 4.22.

Ans: $R_L = 7.5\Omega$

$p_L^{max} = 38$ Watt.

4.23: The variable resistor $R_L$ in the circuit in Fig. 4.105 is adjusted until the power dissipated in the resistor is 250 Watt. Determine the values of $R_L$ that satisfy the condition.

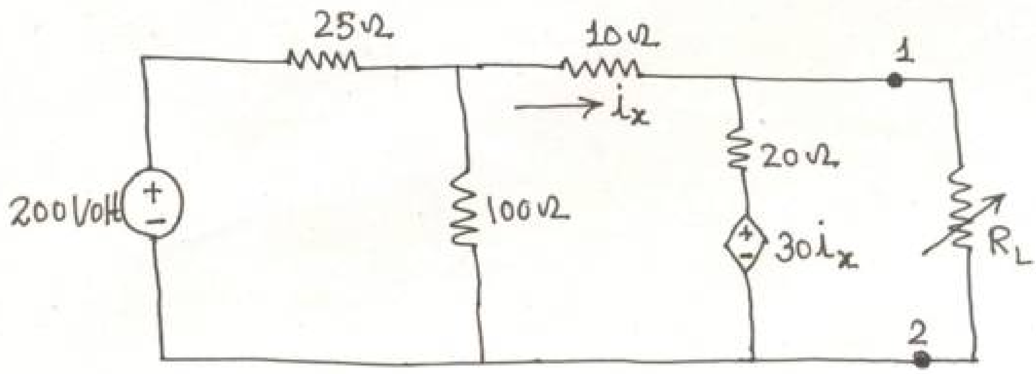



Fig. 4.105: Circuit for Problem 4.23

Ans: $R_L = 2.5\,\Omega$

OR

$R_L = 22.5\,\Omega$

4.24 : Determine the value of $R_L$ that enables the circuit shown in Fig. 4.106 to deliver maximum power to the terminals 1, 2. Find the maximum power delivered to $R_L$

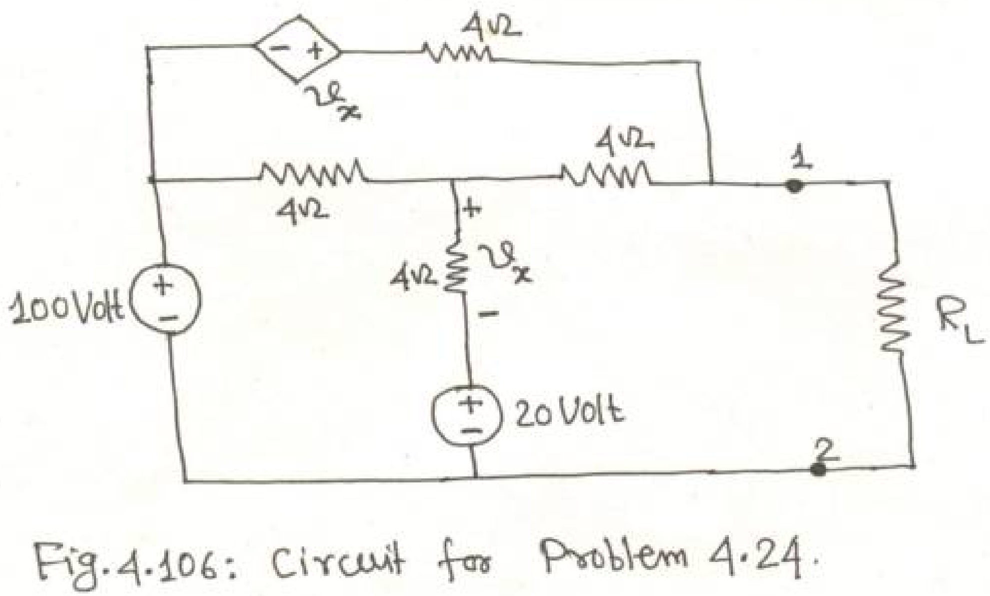



Fig. 4.106: Circuit for Problem 4.24.

Ans: $R_L = 3\,\Omega$

$P_L^{max} = 1200$ Watt.

4.25: For the circuit shown in Fig. 4.107, determine the relationship between $v_o$ and $i_o$.

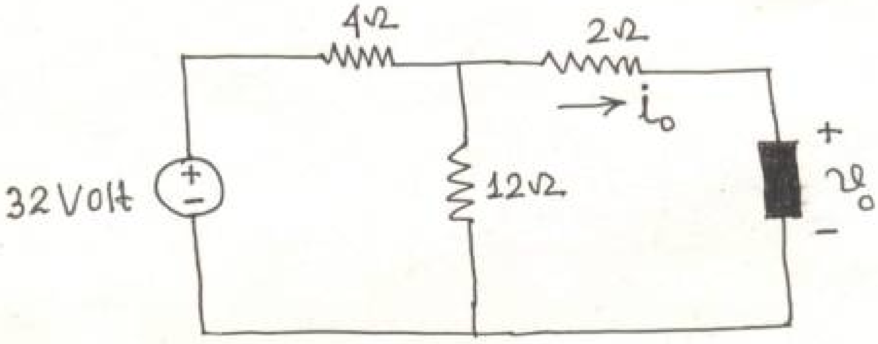



Fig. 4.107: Circuit for Problem 4.25

Ans: $v_o = 24 - 5i_o$