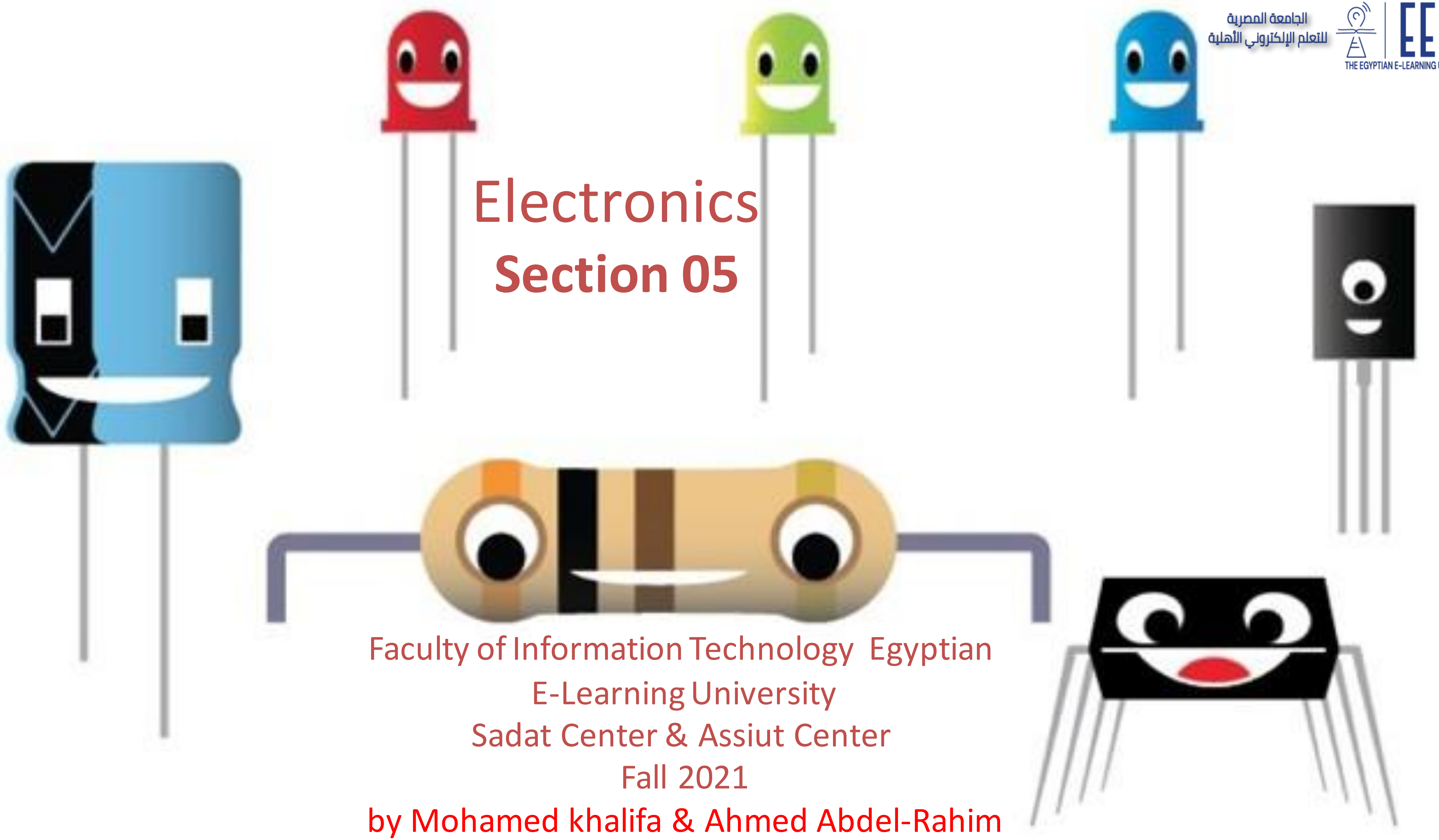

Electronics
Section 05

Faculty of Information Technology Egyptian E-Learning University
Sadat Center & Assiut Center
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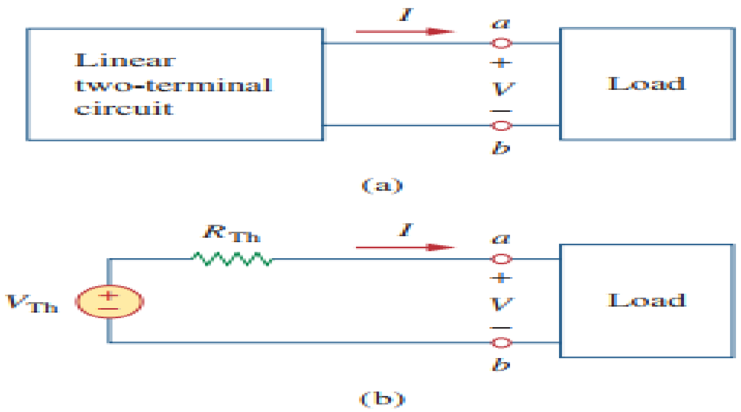
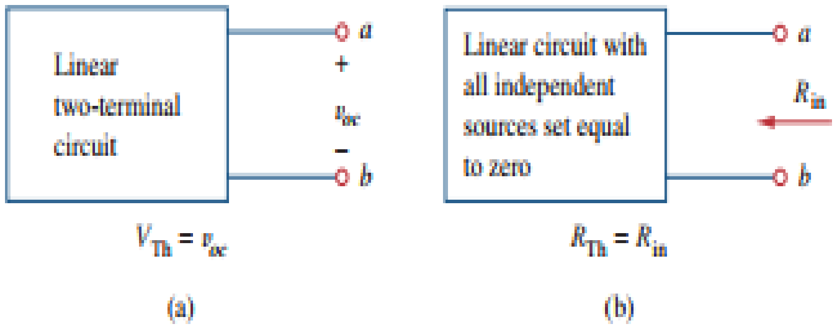
Thevenin's Theorem

Thevenin's theorem states that a linear two-terminal circuit can be replaced by an equivalent circuit consisting of a voltage source V_{Th} in series with a resistor R_{Th}, where V_{Th} is the open-circuit voltage at the terminals and R_{Th} is the input or equivalent resistance at the terminals when the independent sources are turned off.



Replacing a linear two-terminal circuit by its Thevenin equivalent: (a) original circuit, (b) the Thevenin equivalent circuit.



$$I_L = \frac{V_{Th}}{R_{Th} + R_L}$$

$$V_L = R_L I_L = \frac{R_L}{R_{Th} + R_L} V_{Th}$$

Maximum Power Transfer

Maximum power is transferred to the load when the load resistance equals the Thevenin resistance as seen from the load ($R_L = R_{Th}$).

$$p = i^2 R_L = \left(\frac{V_{Th}}{R_{Th} + R_L} \right)^2 R_L$$

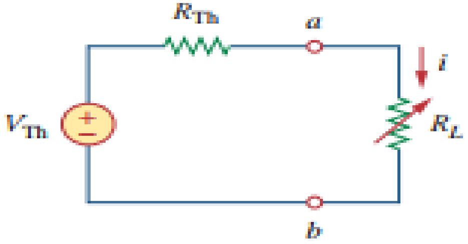


Figure
The circuit used for maximum power transfer.

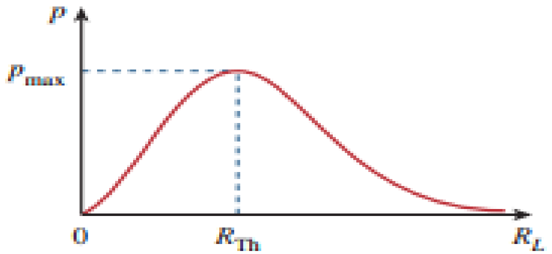
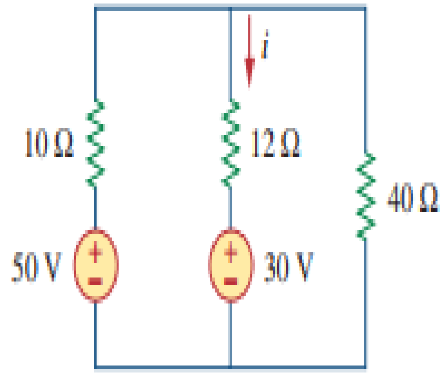


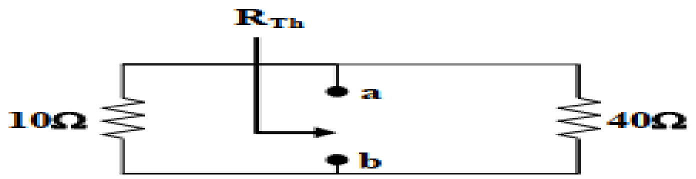
Figure
Power delivered to the load as a function of R_L.

Q1. Solve for the current *i* in the circuit of Figure using Thevenin's theorem. (*Hint:* Find the Thevenin equivalent seen by the 12- Ω resistor.)

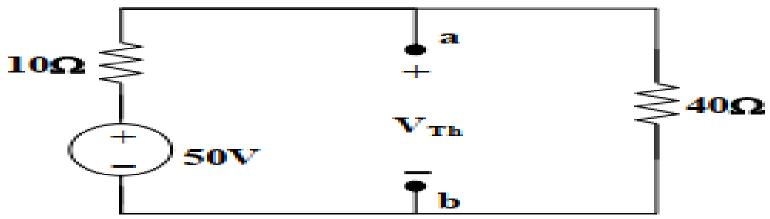


Solution

Remove the 30-V voltage source and the 20-ohm resistor.



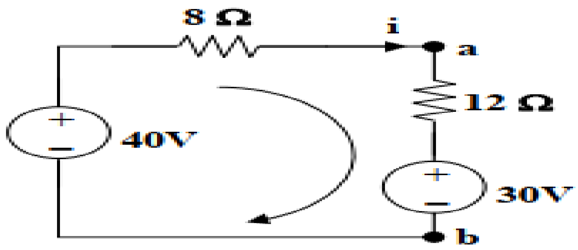
(a)



(b)

From Fig. (a), $R_{Th} = 10||40 = 8$ ohms

From Fig. (b), $V_{Th} = (40/(10 + 40))50 = 40V$

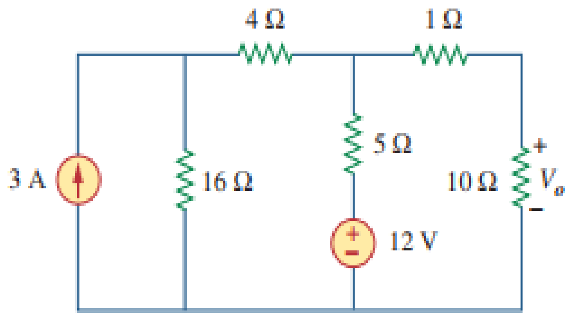


(c)

The equivalent circuit of the original circuit is shown in Fig. (c). Applying KVL,

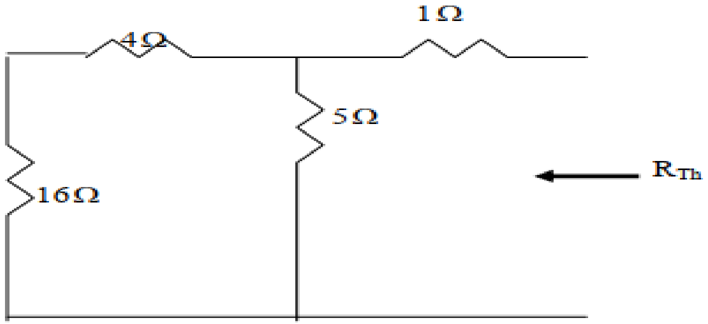
$30 - 40 + (8 + 12)i = 0$, which leads to $i = 500mA$

Q2. Apply Thevenin's theorem to find V_o in the circuit of Figure.



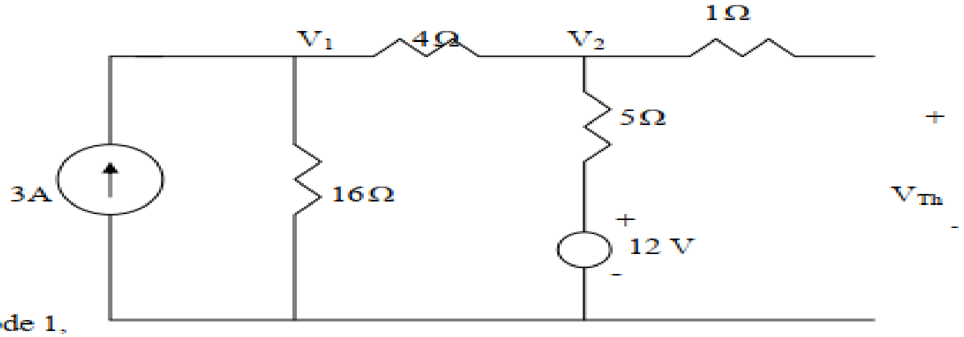
Solution

We find Thevenin equivalent at the terminals of the 10-ohm resistor. For R_{Th}, consider the circuit below.



$$R_{Th} = 1 + 5//(4+16) = 1 + 4 = 5\Omega$$

For V_{Th}, consider the circuit below.



At node 1,

$$3 = \frac{V_1}{16} + \frac{V_1 - V_2}{4} \longrightarrow 48 = 5V_1 - 4V_2 \qquad (1)$$

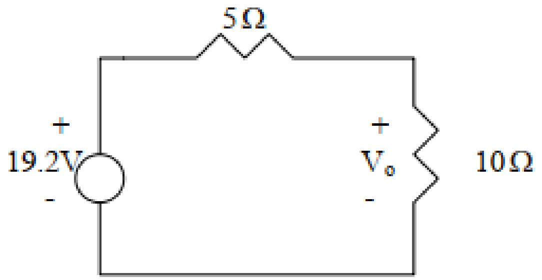
At node 2,

$$\frac{V_1 - V_2}{4} + \frac{12 - V_2}{5} = 0 \longrightarrow 48 = -5V_1 + 9V_2 \qquad (2)$$

Solving (1) and (2) leads to

$V_{Th} = V_2 = 19.2$

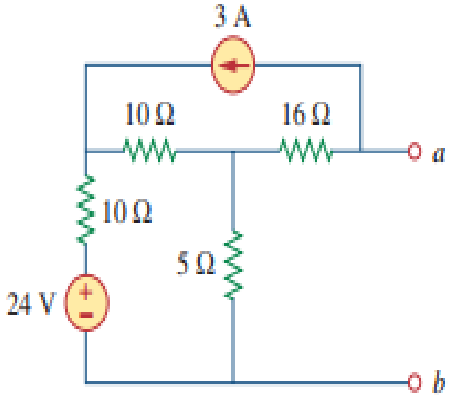
Thus, the given circuit can be replaced as shown below.



Using voltage division,

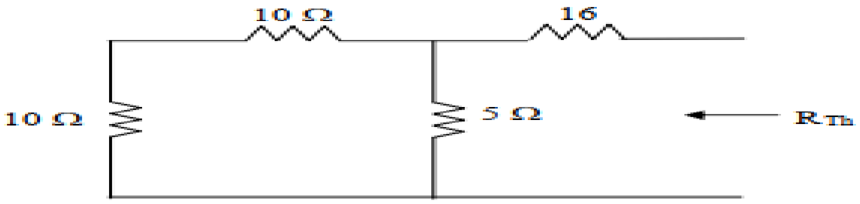
$$V_o = \frac{10}{10+5}(19.2) = 12.8\text{ V}.$$

Q3. Obtain the Thevenin equivalent at terminals of the circuit shown in Figure



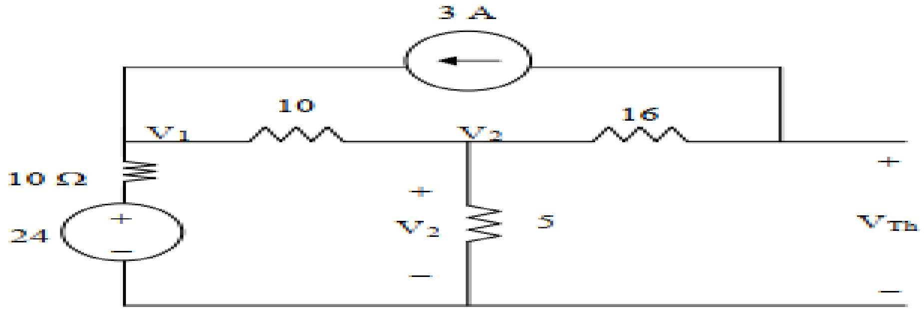
Solution

We obtain R_{Th} using the circuit below.



$$R_{Thev} = 16 + (20||5) = 16 + (20x5)/(20+5) = \mathbf{20\ \Omega}$$

To find V_{Th}, we use the circuit below.



At node 1,

$$\frac{24-V_1}{10}+3=\frac{V_1-V_2}{10} \longrightarrow 54=2V_1-V_2 \quad (1)$$

At node 2,

$$\frac{V_1-V_2}{10}=3+\frac{V_2}{5} \longrightarrow 60=2V_1-6V_2 \quad (2)$$

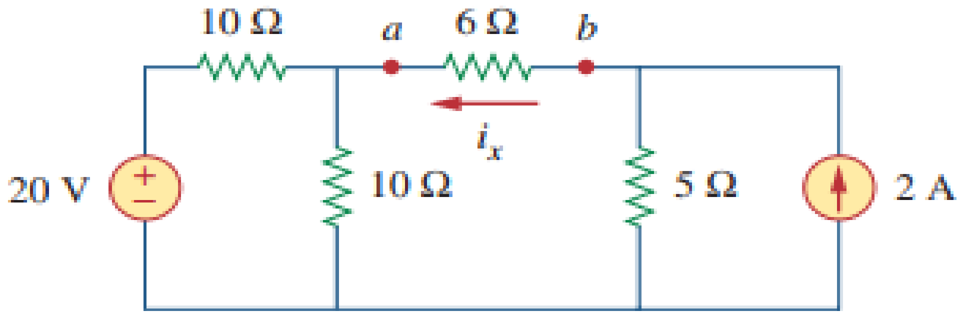
Substracting (1) from (2) gives

$$6 = -5V_2 \text{ or } V_2 = -1.2\text{ V}$$

But

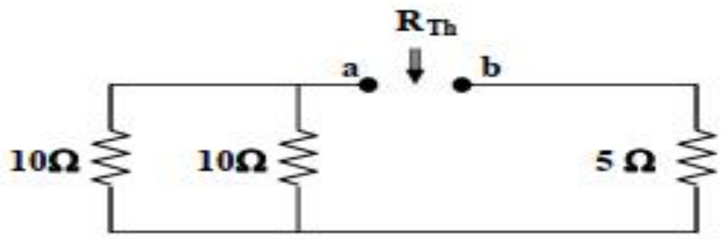
$$-V_2 + 16x3 + V_{Thev} = 0 \text{ or } V_{Thev} = -(48 + 1.2) = \mathbf{-49.2\ V}$$

Q4. Find the Thevenin equivalent looking into terminals *a*-*b* of the circuit in Figure and solve for i_x.

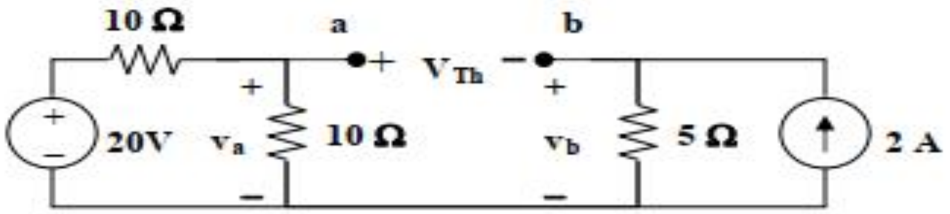


Solution

To find R_{Th}, consider the circuit in Fig. (a).



(a)



(b)

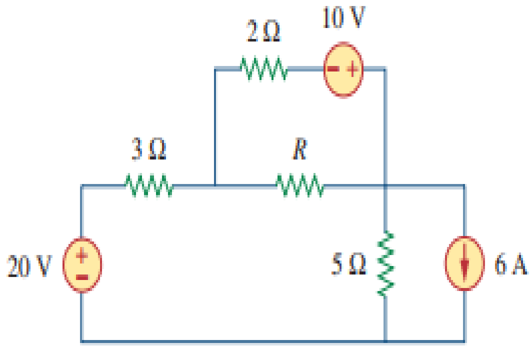
$$R_{Th} = 10||10 + 5 = \mathbf{10\ ohms}$$

To find V_{Th}, consider the circuit in Fig. (b).

$$v_b = 2x5 = 10 \text{ V}, \quad v_a = 20/2 = 10 \text{ V}$$

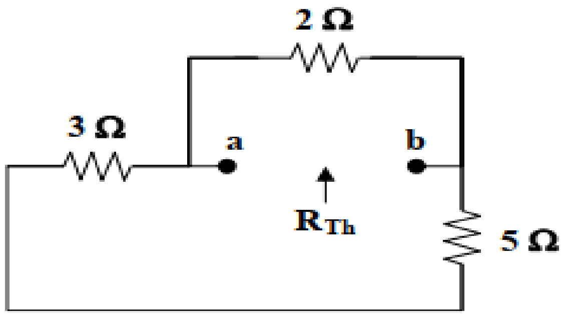
But, $\quad -v_a + V_{Th} + v_b = 0, \text{ or } V_{Th} = v_a - v_b = \mathbf{0\ volts}$

Q5. Find the maximum power that can be delivered to the resistor R in the circuit of Figure.

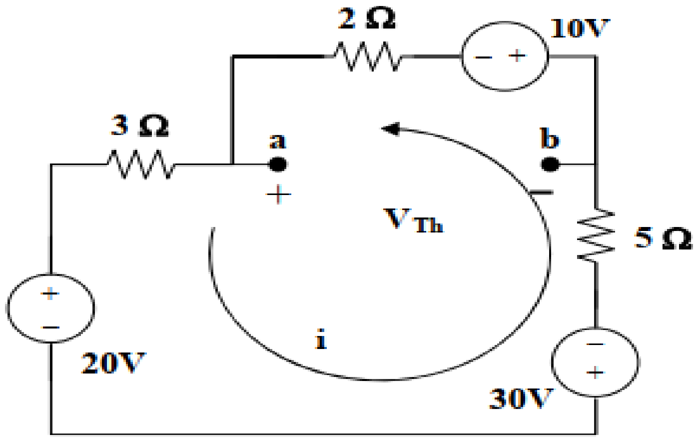


Solution

We first find the Thevenin equivalent at terminals a and b. We find R_{Th} using the circuit in Fig. (a).



(a)



(b)

$$R_{Th} = 2||(3+5) = 2||8 = \mathbf{1.6\ ohms}$$

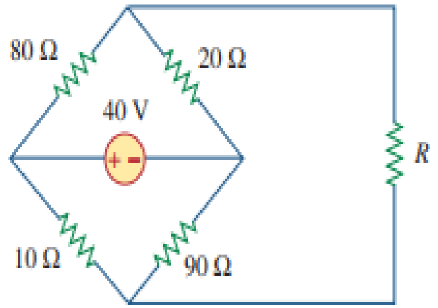
By performing source transformation on the given circuit, we obatin the circuit in (b). We now use this to find V_{Th}.

$$10i + 30 + 20 + 10 = 0, \text{ or } i = -6$$

$$V_{Th} + 10 + 2i = 0, \text{ or } V_{Th} = 2\text{ V}$$

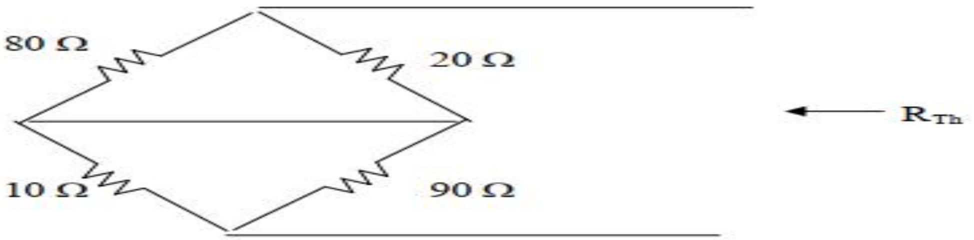
$$p = V_{Th}^2/(4R_{Th}) = (2)^2/[4(1.6)] = \mathbf{625\ m\ watts}$$

Q6. The variable resistor R in Figure is adjusted until it absorbs the maximum power from the circuit.
(a) Calculate the value of R for maximum power.
(b) Determine the maximum power absorbed by R.



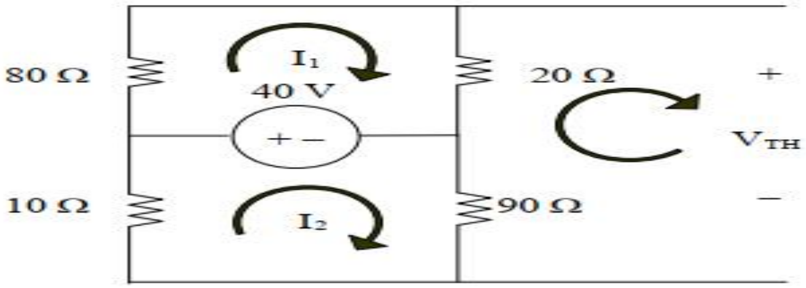
Solution

We first find the Thevenin equivalent. We find R_{Th} using the circuit below.



$$R_{Th} = 20//80 + 90//10 = 16 + 9 = 25\ \Omega$$

We find V_{Th} using the circuit below. We apply mesh analysis.

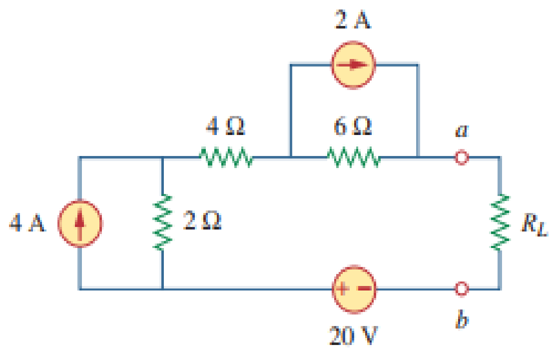


$$(80+20)i_1 - 40 = 0 \longrightarrow i_1 = 0.4$$
$$(10+90)i_2 + 40 = 0 \longrightarrow i_2 = -0.4$$
$$-90i_2 - 20i_1 + V_{Th} = 0 \longrightarrow V_{Th} = -28\ \text{V}$$

(a) $R = R_{Th} = \mathbf{25\ \Omega}$

(b) $P_{max} = \dfrac{V_{Th}^2}{4R_{Th}} = \dfrac{(28)^2}{100} = \underline{7.84\ \text{W}}$

Q7. (a) For the circuit in Figure, obtain the Thevenin equivalent at terminals a-b
(b) Calculate the current in $R_L = 8\ \Omega$.
(c) Find for maximum power deliverable to R_L.
(d) Determine that maximum power.

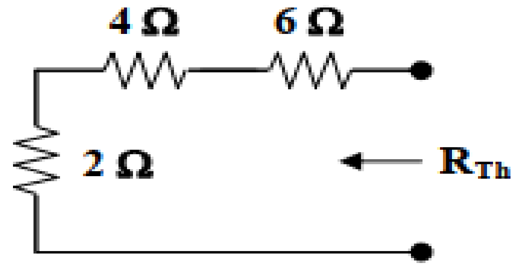


Solution

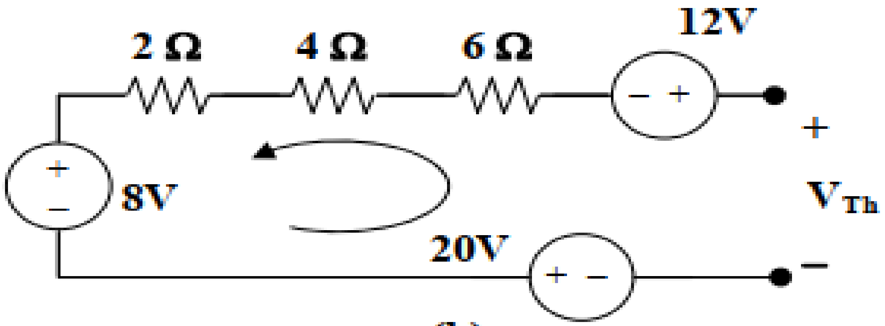
(a) R_{Th} and V_{Th} are calculated using the circuits shown in Fig. (a) and (b) respectively.

From Fig. (a), $R_{Th} = 2 + 4 + 6 =$ **12 ohms**

From Fig. (b), $-V_{Th} + 12 + 8 + 20 = 0$, or $V_{Th} =$ **40 V**



(a)



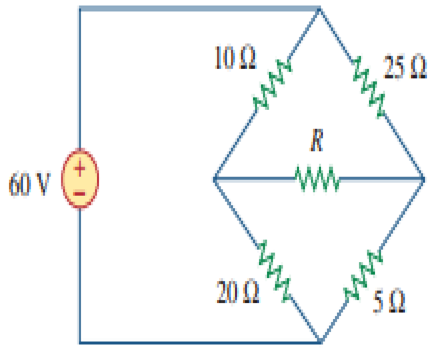
(b)

(b) $i = V_{Th}/(R_{Th} + R) = 40/(12 + 8) =$ **2A**

(c) For maximum power transfer, $R_L = R_{Th} =$ **12 ohms**

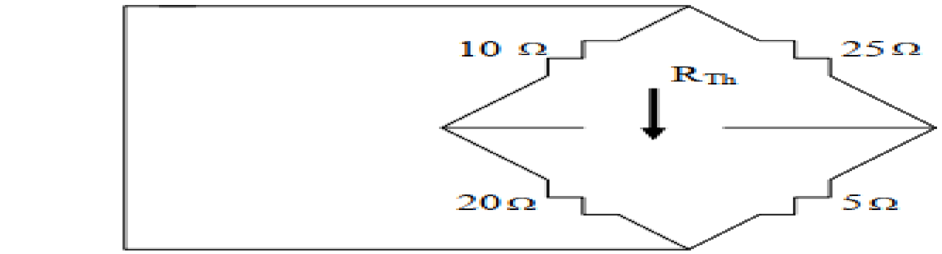
(d) $p = V_{Th}^2/(4R_{Th}) = (40)^2/(4x12) =$ **33.33 watts**.

Q8. Determine the maximum power that can be delivered to the variable resistor R in the circuit of Figure.

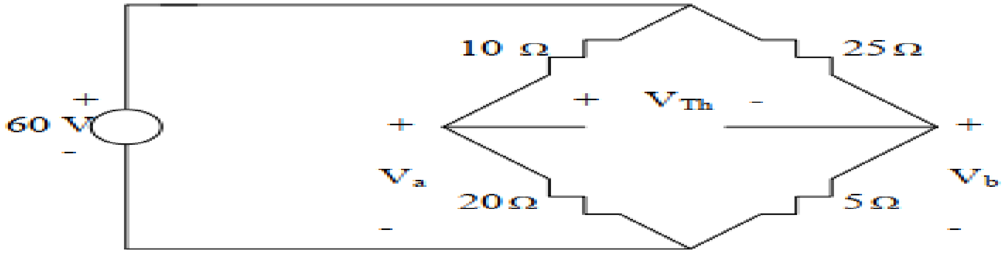


Solution

Find the Thevenin's equivalent circuit across the terminals of R.



$$R_{Th} = 10 // 20 + 25 // 5 = 325/30 = 10.833\Omega$$



$$V_a = \frac{20}{30}(60) = 40, \qquad V_b = \frac{5}{30}(60) = 10$$

$$-V_a + V_{Th} + V_b = 0 \longrightarrow V_{Th} = V_a - V_b = 40 - 10 = 30\text{ V}$$

$$p_{max} = \frac{V_{Th}^2}{4R_{Th}} = \frac{30^2}{4x10.833} = 20.77\text{ W.}$$