Electronics
Section 04

Faculty of Information Technology Egyptian E-Learning University
Ain Shams Center & Assiut Center
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Superposition

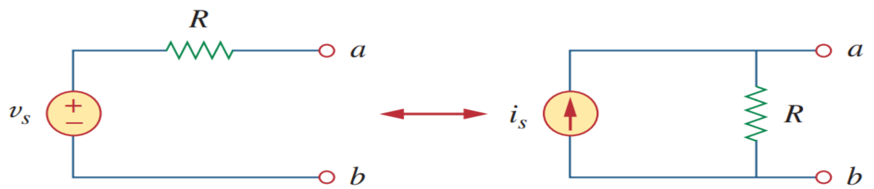
The **superposition** principle states that the voltage across (or current through) an element in a linear circuit is the algebraic sum of the voltages across (or currents through) that element due to each independent source acting alone.

Steps to Apply Superposition Principle:

1. **Turn off all independent sources except one source. Find the output (voltage or current) due to that active source using the techniques covered in previous lectures.**
2. **Repeat step 1 for each of the other independent sources.**
3. **Find the total contribution by adding algebraically all the contributions due to the independent sources.**

Source Transformation

A **source transformation** is the process of replacing a voltage source v_s in series with a resistor R by a current source i_s in parallel with a resistor R, or vice versa.



$$v_s = i_s R \qquad \text{or} \qquad i_s = \frac{v_s}{R}$$

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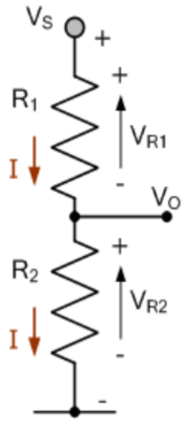
•Voltage Divider Rule

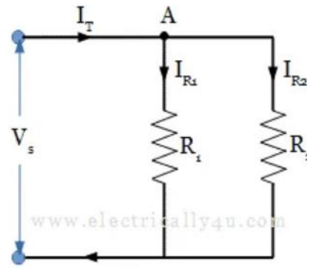
Voltage Divider circuits are used to produce different voltage levels from a common voltage source but the current is the same for all components in a series cicruit

$$\therefore V_{R2} = V_S\left(\frac{R_2}{R_1 + R_2}\right)$$

$$\therefore V_{R1} = V_S\left(\frac{R_1}{R_1 + R_2}\right)$$



•Current Divider prove



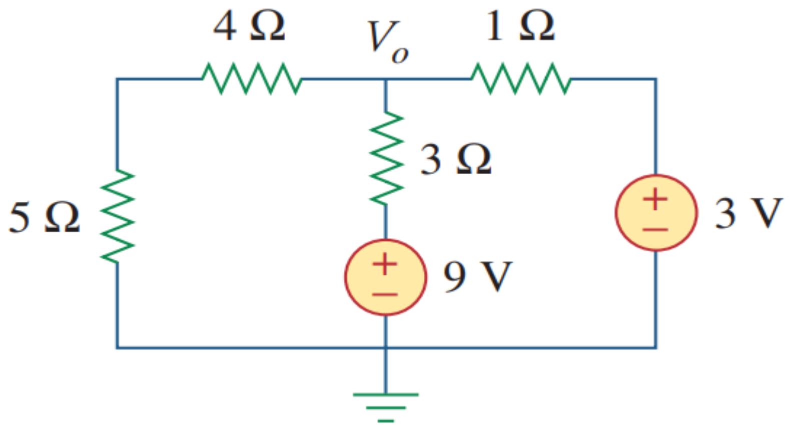
$$I_{R1} = \frac{V_s}{R_1} = \frac{I_T}{R_1}\left(\frac{R_1 . R_2}{R_1 + R_2}\right)$$

$$I_{R1} = I_T\left(\frac{R_2}{R_1 + R_2}\right)$$

$$I_{R2} = \frac{V_s}{R_2} = \frac{I_T}{R_2}\left(\frac{R_1 . R_2}{R_1 + R_2}\right)$$

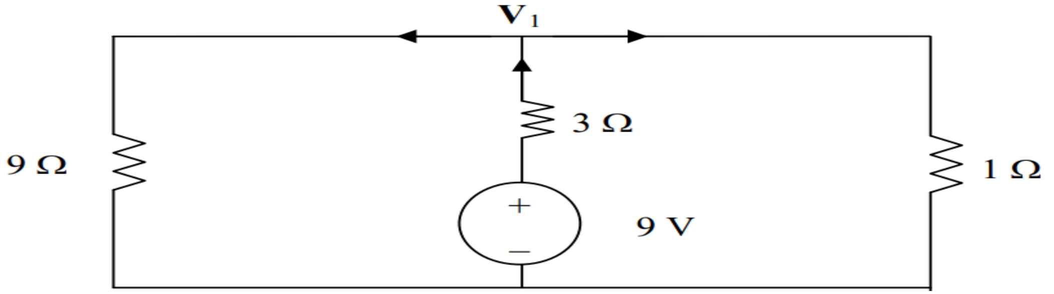
$$I_{R2} = I_T\left(\frac{R_1}{R_1 + R_2}\right)$$

Q1. Using superposition, find V_0 in the given circuit.



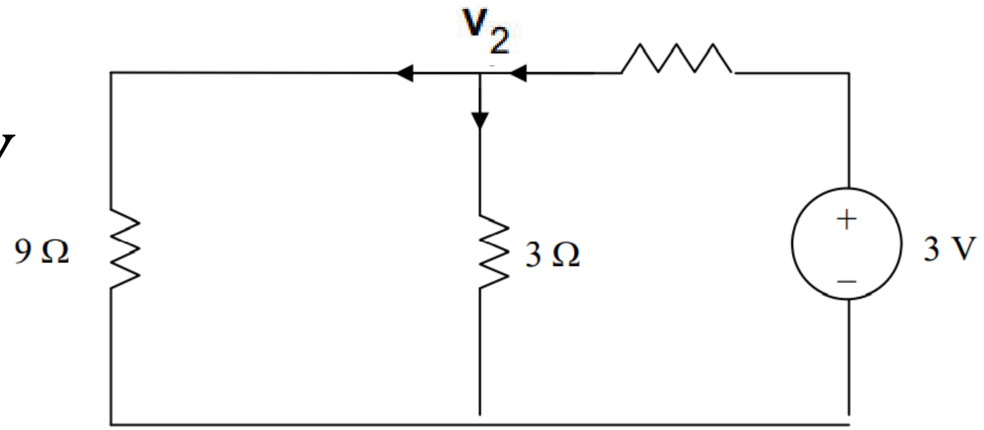
Solution

Let $V_o = V_1 + V_2$, where V_1 and V_2 are due to 9-V and 3-V sources respectively. To find V_1, consider the circuit below.



$$\frac{9-V_1}{3} = \frac{V_1}{9} + \frac{V_1}{1} \longrightarrow V_1 = 27/13 = 2.0769\ V$$

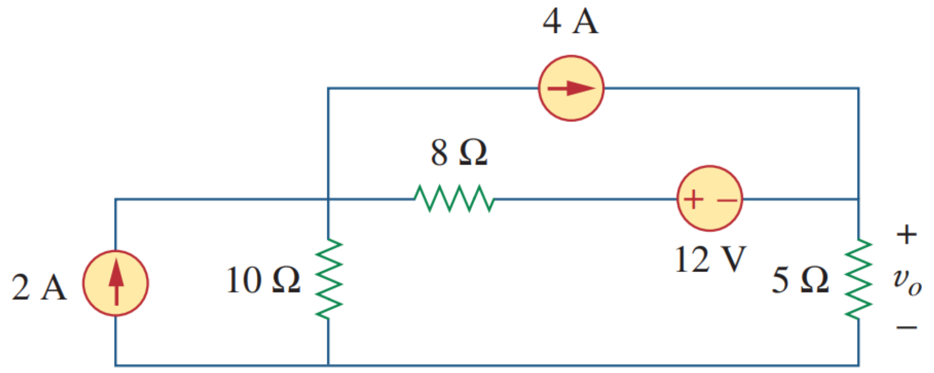
To find V_2, consider the circuit below.



$$\frac{V_2}{9} + \frac{V_2}{3} = \frac{3-V_2}{1} \longrightarrow V_2 = 27/13 = 2.0769\ V$$

$$V_o = V_1 + V_2 = \mathbf{4.1538\ \ V}$$

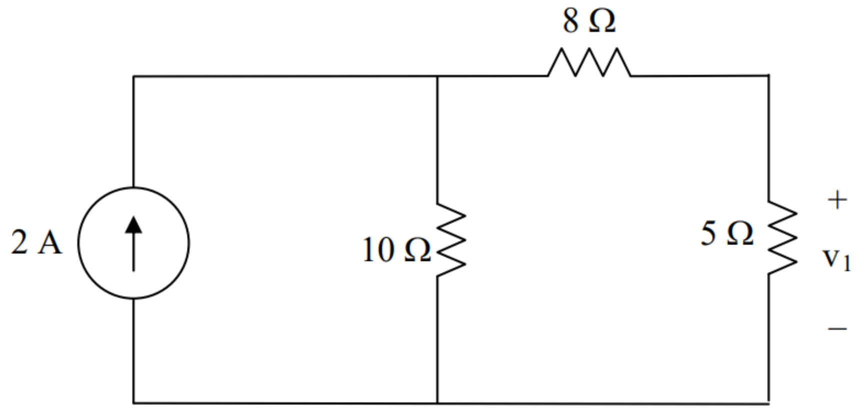
Q2. Use superposition to find V_0 in the given circuit.



Solution

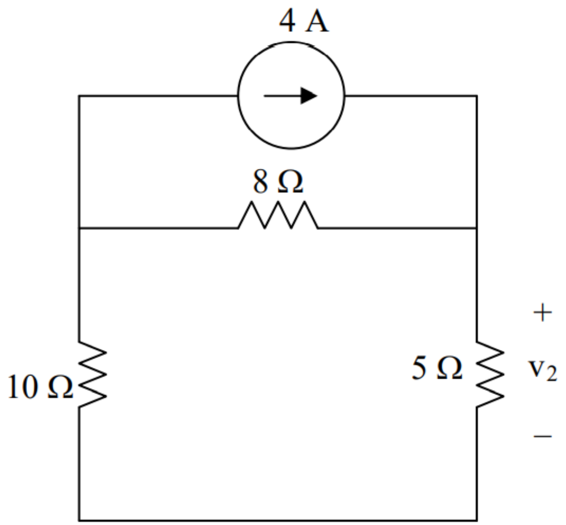
Let $v_o = v_1 + v_2 + v_3$, where v_1, v_2, and v_3 are due to the independent sources. To find v_1, consider the circuit below.

$$v_1 = I_{5\Omega}R = 5I_{5\Omega} = 5x\frac{10}{10+8+5}x2 = 4.3478 \quad V$$



To find v_2, consider the circuit below.

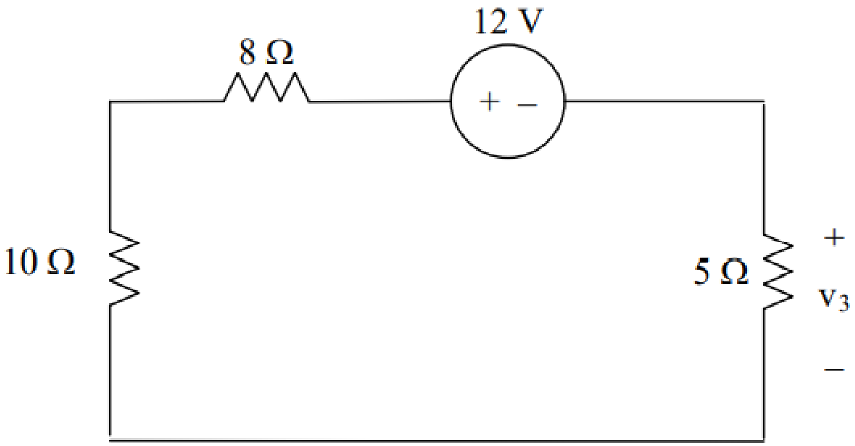
$$v_2 = I_{5\Omega}R = 5I_{5\Omega} = 5x\frac{8}{8+10+5}x4 = 6.9565 \quad V$$



To find v_3, consider the circuit below.

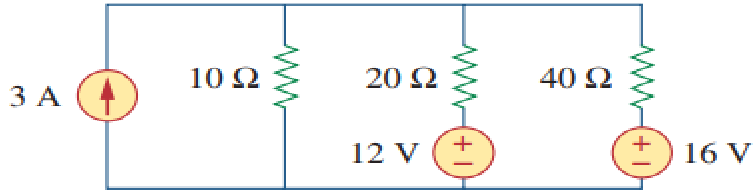
$$v_3 = -12\left(\frac{5}{5+10+8}\right) = -2.6087 \quad V$$

(The –Ve sign here indicates that the current in the resistance due to this source, is opposite to the current due to the other sources)



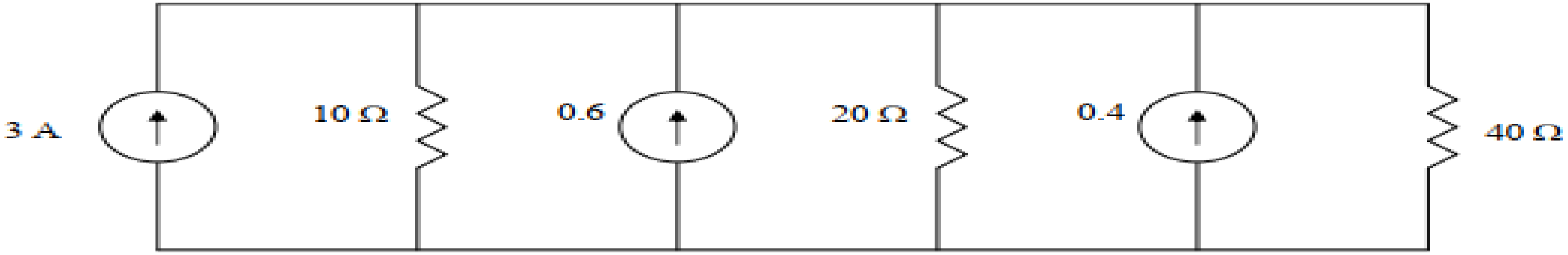
$$v_o = v_1 + v_2 + v_3 = \underline{8.6956 \text{ V}}$$

Q3. Use source transformation to reduce the circuit in Figure to a single voltage source in series with a single resistor.



Solution

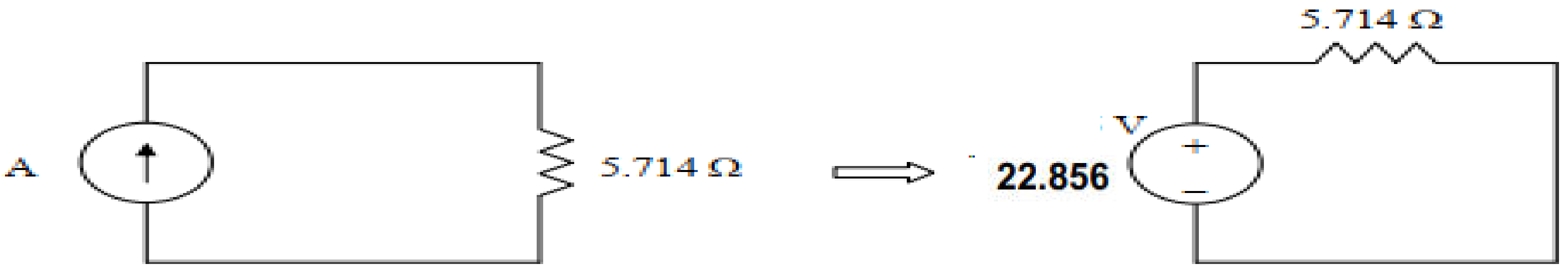
Convert the voltage sources to current sources and obtain the circuit shown below.



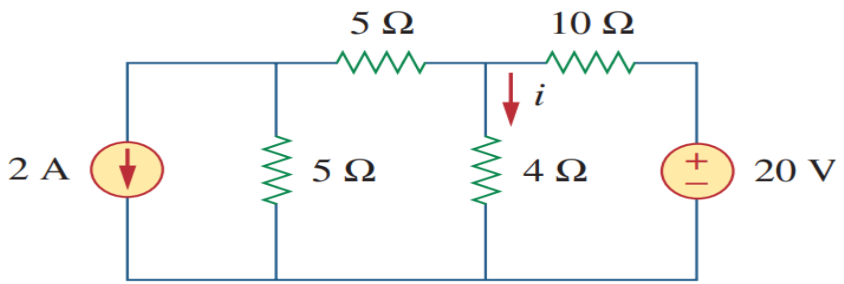
$$\frac{1}{R_{eq}} = \frac{1}{10} + \frac{1}{20} + \frac{1}{40} = 0.1 + 0.05 + 0.025 = 0.175 \longrightarrow R_{eq} = 5.714\ \Omega$$

$I_{eq} = 3 + 0.6 + 0.4 = 4$

Thus, the circuit is reduced as shown below. Please note, we that this is merely an exercise in combining sources and resistors. The circuit we have is an equivalent circuit which has no real purpose other than to demonstrate source transformation. In a practical situation, this would need some kind of reference and a use to an external circuit to be of real value.

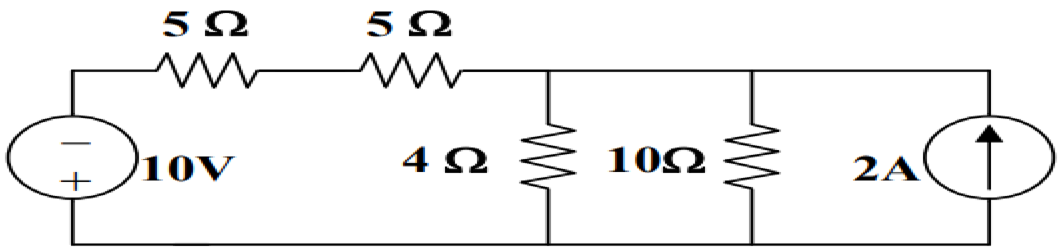


Q4. For the circuit in the given figure, use source transformation to find i.



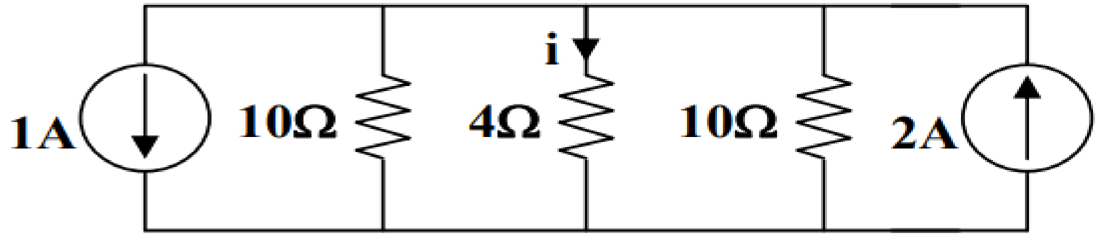
Solution

We transform the two sources to get the circuit shown in Fig. (a).



(a)

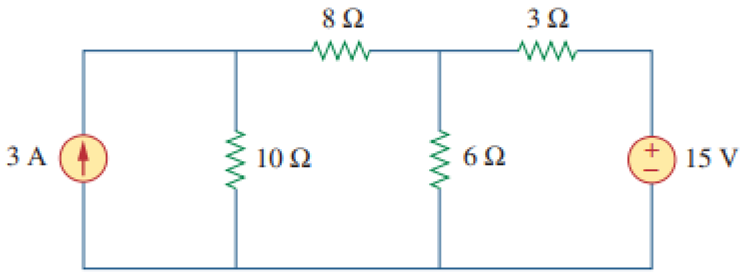
We now transform only the voltage source to obtain the circuit in Fig. (b).



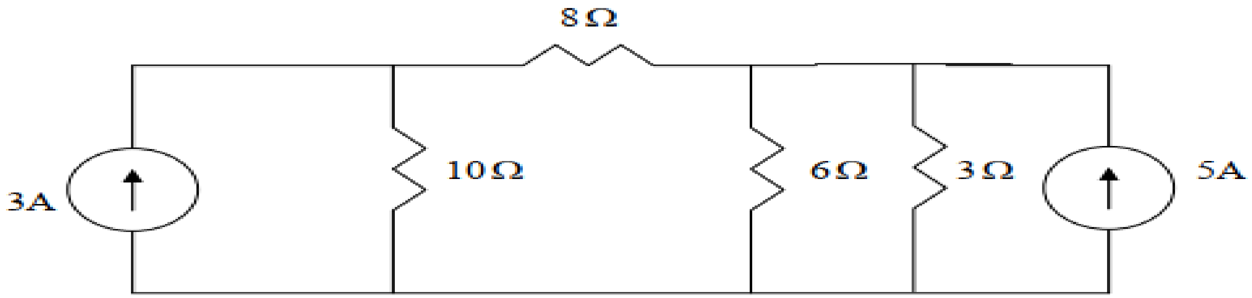
(b)

$10||10 = 5$ ohms, $i = [5/(5+4)](2-1) = 5/9 =$ **555.5 mA**

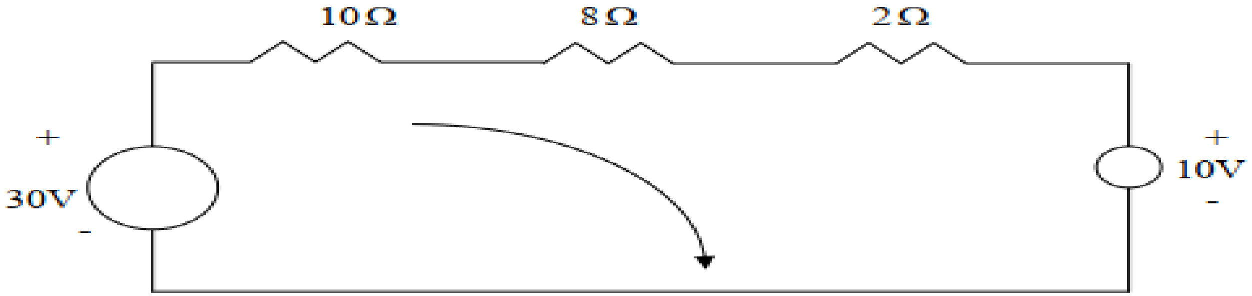
Q5. Referring to Figure, use source transformation to determine the current and power absorbed by the 8-Ω resistor.



Solution



3//6 = 2-ohm. Convert the current sources to voltages sources as shown below.

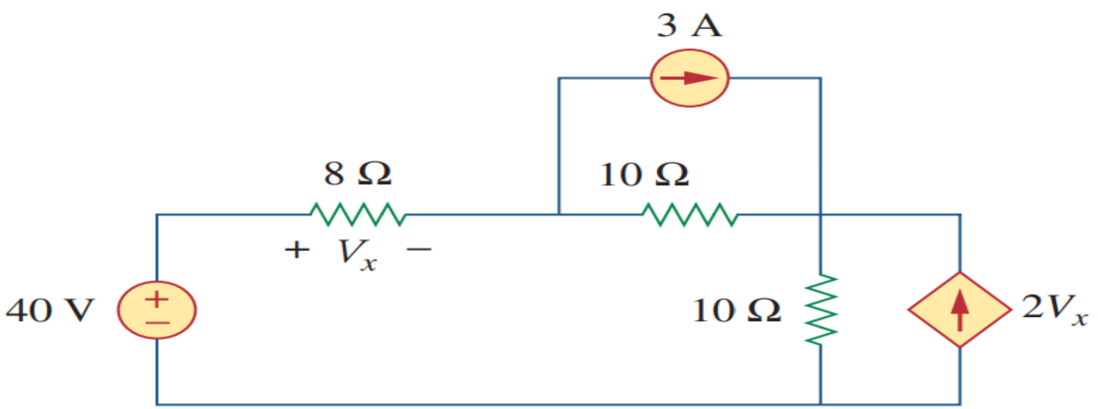


Applying KVL to the loop gives

$-30 + 10 + I(10 + 8 + 2) = 0 \longrightarrow \mathbf{I = 1\ A}$

$p = VI = I^2 R = \mathbf{8\ W}$

Q6. Use source transformation to determine V_x.



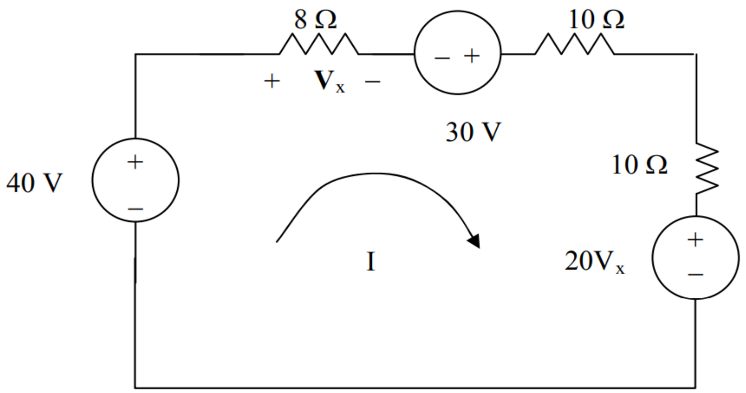
Solution

Transform the two current sources in parallel with the resistors into their voltage source equivalents yield,

a 30-V source in series with a 10-Ω resistor and a $20V_x$-V sources in series with a 10-Ω resistor.

We now have the following circuit,

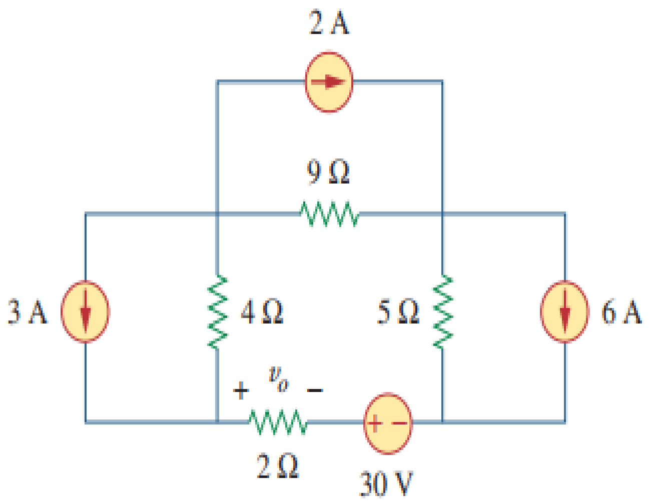
We now write the following mesh equation and constraint equation which will lead to a solution for V_x,



$28I - 70 + 20V_x = 0$ or $28I + 20V_x = 70$, but $V_x = 8I$ which leads to

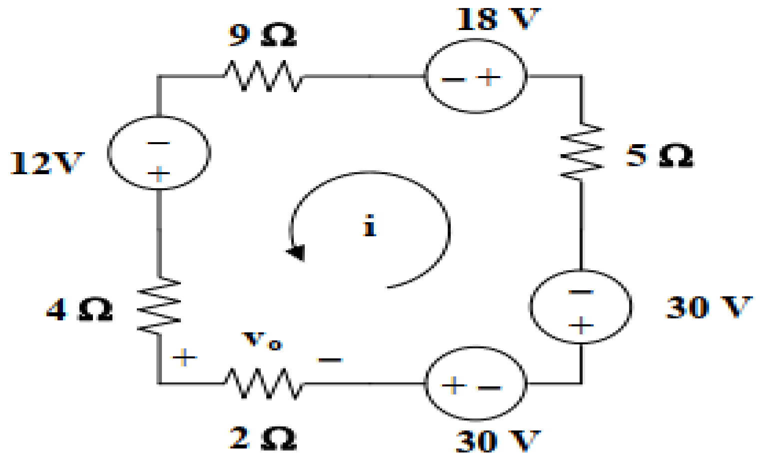
$28I + 160I = 70$ or $I = 0.3723$ A or $V_x = \mathbf{2.978}$ **V**.

Q7. Obtain V_0 in the circuit of Figure using source transformation.



Solution

Transforming only the current source gives the circuit below.



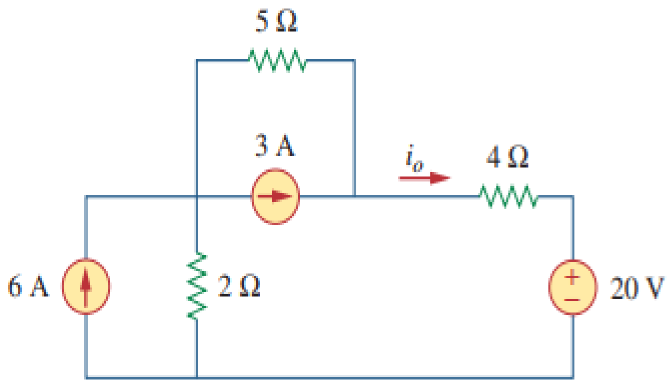
Applying KVL to the loop gives,

$$-(4 + 9 + 5 + 2)i + 12 - 18 - 30 - 30 = 0$$

$$20i = -66 \quad \text{which leads to} \quad i = -3.3$$

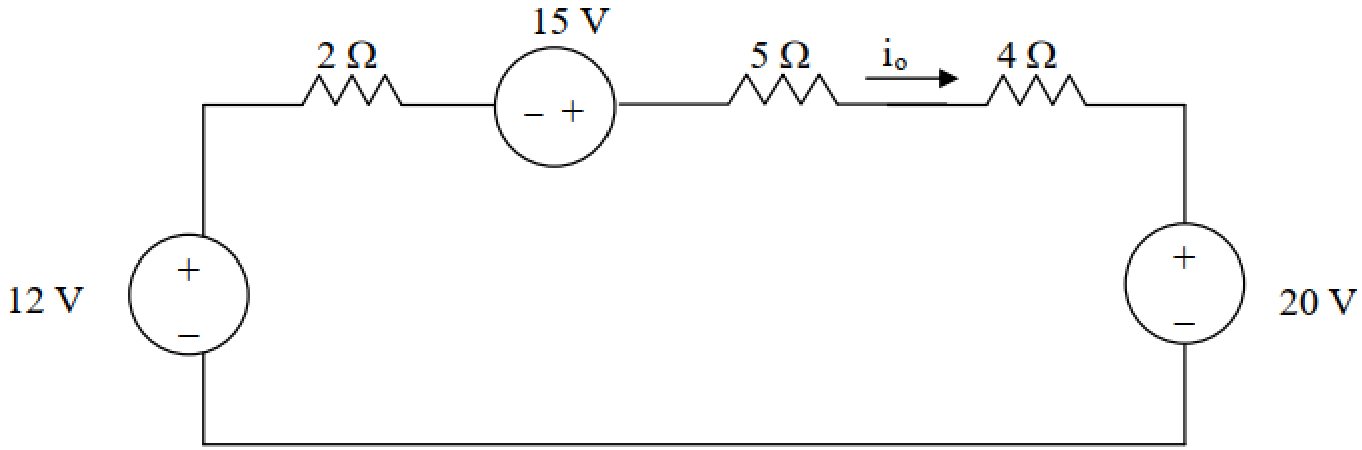
$v_o = 2i = -6.6$ **V**

Q8. Use source transformation to find i_0 in the circuit of the Figure.



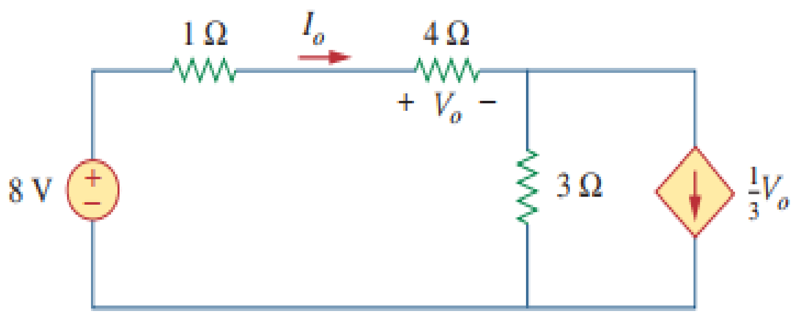
Solution

Transforming the current sources gives the circuit below.



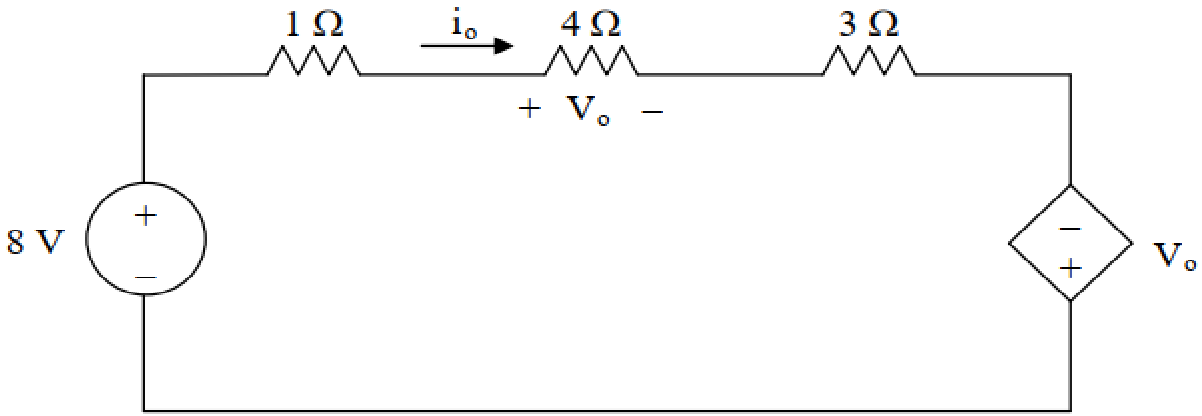
$-12 + 11i_o - 15 + 20 = 0$ or $11i_o = 7$ or $i_o =$ **636.4 mA**.

Q9. Use source transformation to find i_0 in Figure.



Solution

Convert the dependent current source to a dependent voltage source as shown below.



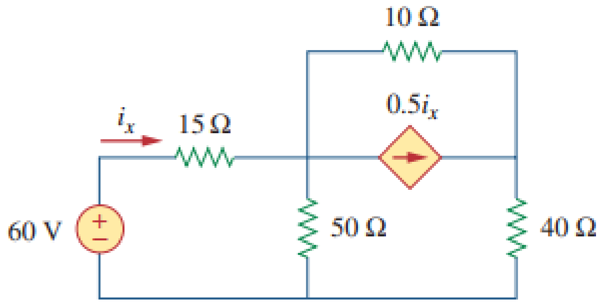
Applying KVL,

$$-8 + i_o(1+4+3) - V_o = 0$$

But $V_o = 4i_o$

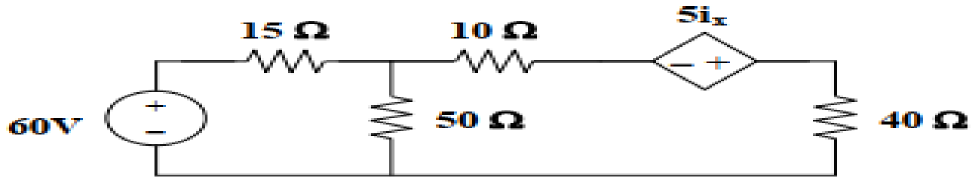
$$-8 + 8i_o - 4i_o = 0 \longrightarrow i_o = \underline{2\ A}$$

Q10. Use source transformation to find in the circuit of Figure.

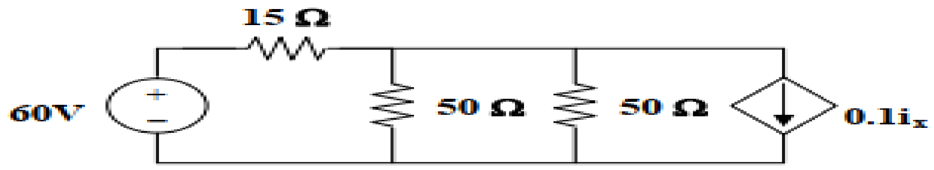


Solution

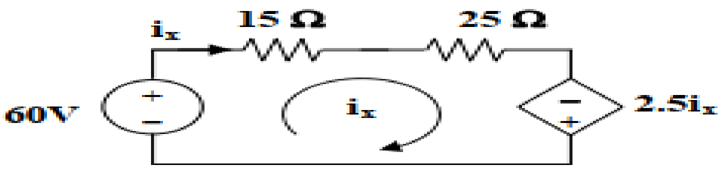
As shown in Fig. (a), we transform the dependent current source to a voltage source,



(a)



(b)



(c)

In Fig. (b), 50||50 = 25 ohms. Applying KVL in Fig. (c),

$-60 + 40i_x - 2.5i_x = 0$, or $i_x = 1.6$ A