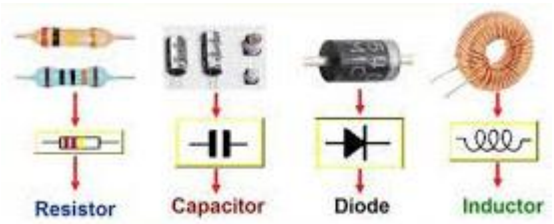
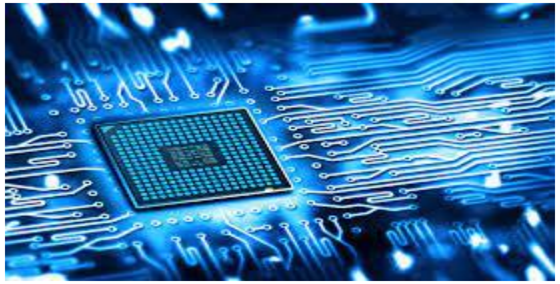
Electronics 1

BSC 113

Summer 2021-2022

Lecture 3





Techniques of Circuit Analysis

INSTRUCTOR

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➢ Contents

Kirchhoff's law

- current
- voltage

❑ 2.1 Kirchhoff's current law

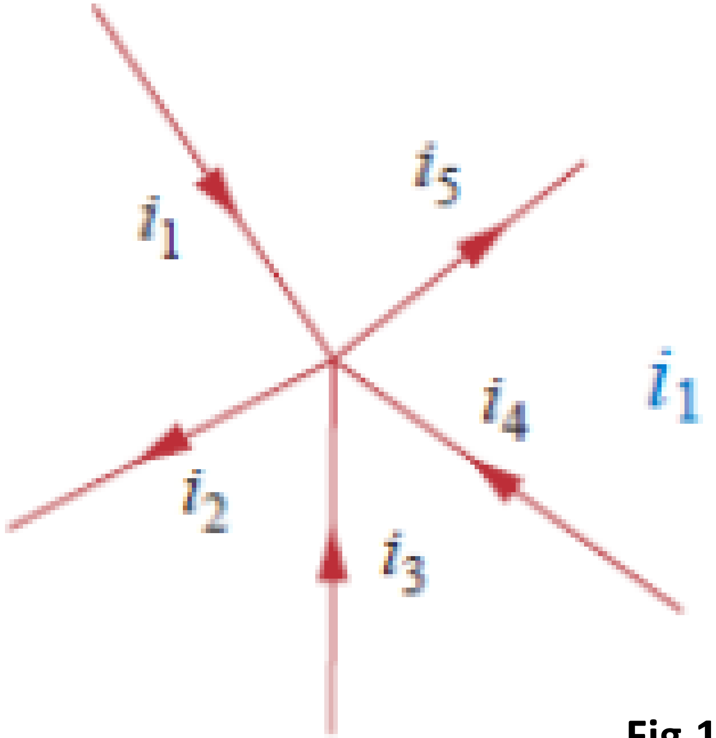
- In Kirchhoff's current law (KCL) states that the algebraic sum of currents entering a node (or a closed boundary) is zero. Mathematically, KCL implies that

$$\sum_{n=1}^{N} i_n = 0$$

- where N is the number of branches connected to the node and i_n is the n-th current entering (or leaving) the node.

❑ 2.1 Kirchhoff's current law

- As shown in figure1, by this law, currents entering a node may be regarded as positive, while currents leaving the node may be taken as negative or vice versa.



$$i_1 + (-i_2) + i_3 + i_4 + (-i_5) = 0$$

Fig.1: Example on KCL

❑ 2.1 Kirchhoff's current law

➢ As shown in figure 2, the sum of the currents entering a node is equal to the sum of the currents leaving the node.

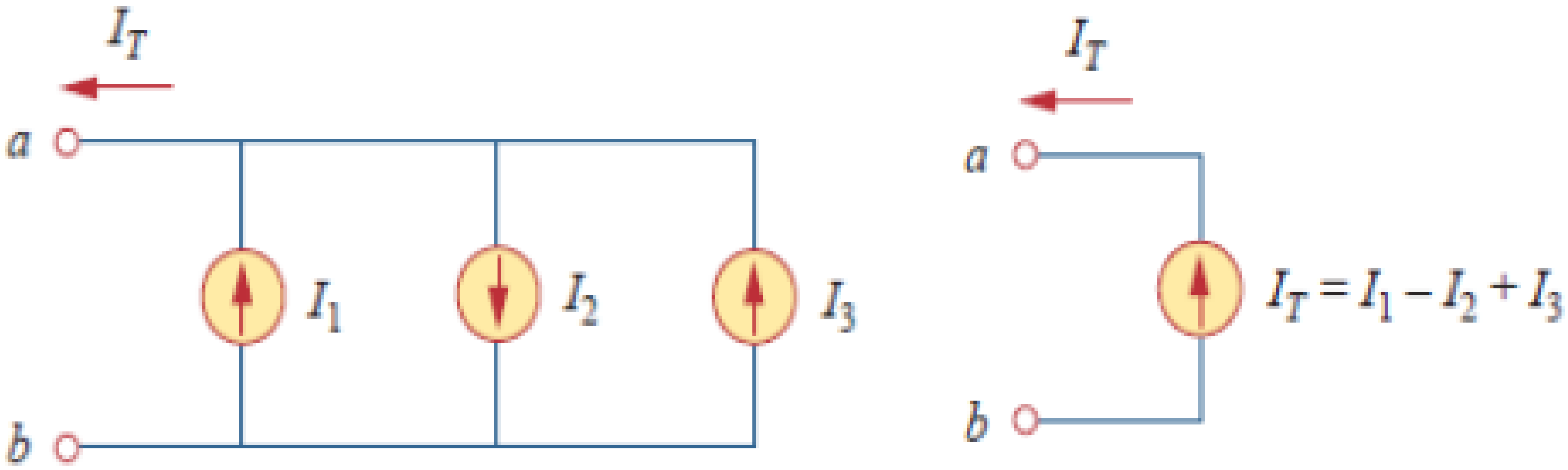


Fig.2: Example on KCL

❑ 2.2 Kirchhoff's voltage law

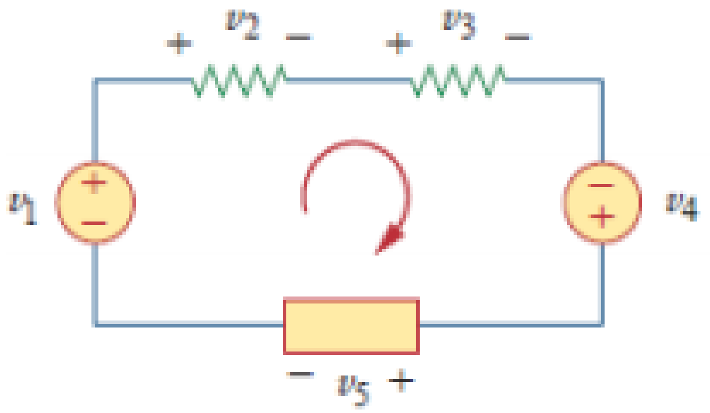
- In Kirchhoff's voltage law (KVL) states that the algebraic sum of all voltages around a closed path (or loop) is zero. Mathematically, KVL implies that

$$\sum_{m=1}^{M} v_m = 0$$

- where M is the number of voltages in the loop (or the number of branches in the loop) and v_m is the m-th voltage.

❑ 2.2 Kirchhoff's voltage law

- As shown in figure 3, by this law, The sign on each voltage is the polarity of the terminal encountered first as we travel around the loop. We can start with any branch and go around the loop either clockwise or counterclockwise.
- In other words, sum of voltage drops = sum of voltage rises



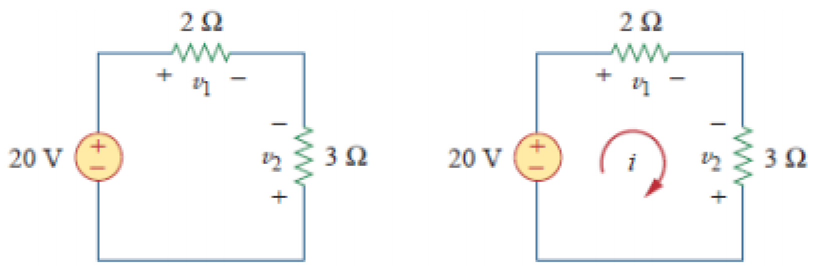
$$-v_1 + v_2 + v_3 - v_4 + v_5 = 0$$

$$v_2 + v_3 + v_5 = v_1 + v_4$$

Fig. 3: Example on KVL

❑ Example 2.1

- For the circuit in the following figure, find voltages v1 and v2.



- Answer: To find v1 and v2 we apply Ohm's law and Kirchhoff's voltage law. Assume that current i flows through the loop as shown in Fig. From Ohm's law,

$$v1=2i, \; v2 = -3i.$$

- Applying KVL around the loop gives

$$-20 + v1 - v2 = 0$$

we obtain i = 4 A. v1= 8 V and v2 = -12 V

❑ 2.3 Series and parallel resistance

- The process of combining the resistors is facilitated by combining two of them at a time. Consider the single-loop circuit of figure 4. The two resistors are in series, since the same current i flows in both. Applying Ohm's law to each of the resistors, we obtain

$$v1 = i\ R1 \text{ and } v2 = i\ R2$$

$$-v + v1 + v2 = 0$$

$$v = v1 + v2 = i(R1 + R2)$$

$$i = \frac{v}{(R1 + R2)}$$

$$v = i\ R_{eq} \qquad\qquad R_{eq} = R1 + R2$$

❑ 2.3 Series and parallel resistance

➢ Now we can say the equivalent resistance of any number of resistors connected in series is the sum of the individual resistances.

$$R_{eq} = \sum_{i=1}^{N} R_i$$

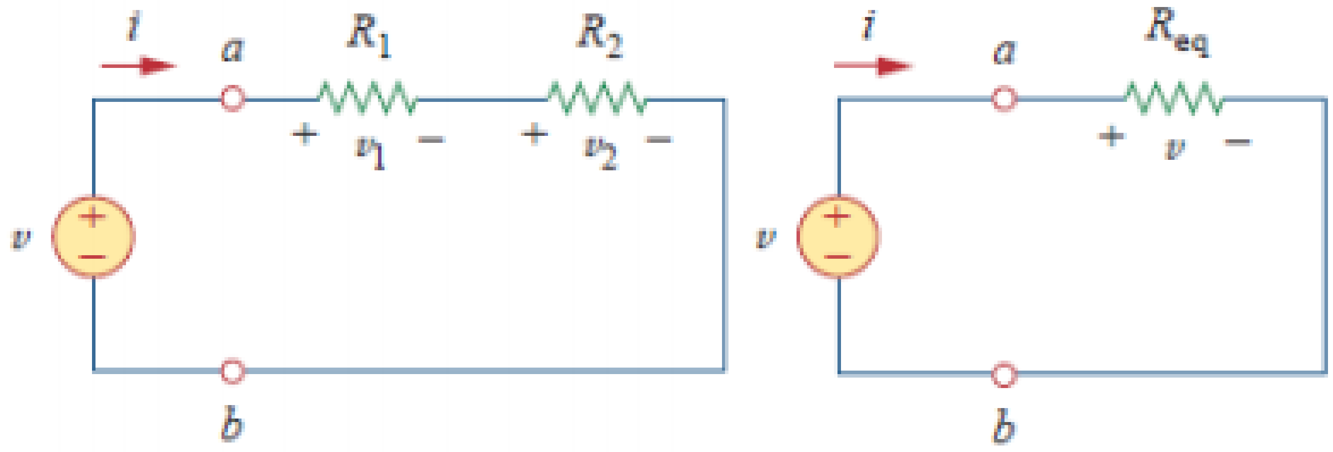


Fig. 4: A single-loop circuit with two resistors in series.

2.3 Series and parallel resistance

- If $R1 = R2 = \cdots = RN = R$, then

$$Req = NR$$

- where two resistors are connected in parallel and therefore have the same voltage across them as shown in figure 5. From Ohm's law,

$$v = iR1 = iR2$$

$$i_1 = \frac{v}{R_1}, \qquad i_2 = \frac{v}{R_2}$$

$$i = i_1 + i_2 = \frac{v}{R_1} + \frac{v}{R_2} = v\left(\frac{1}{R_1} + \frac{1}{R_2}\right) = \frac{v}{R_{eq}}$$

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$R_{eq} = \frac{R_1 R_2}{R_1 + R_2}$$

❑ 2.3 Series and parallel resistance

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots + \frac{1}{R_N}$$

- The equivalent resistance of two parallel resistors is equal to the product of their resistances divided by their sum.

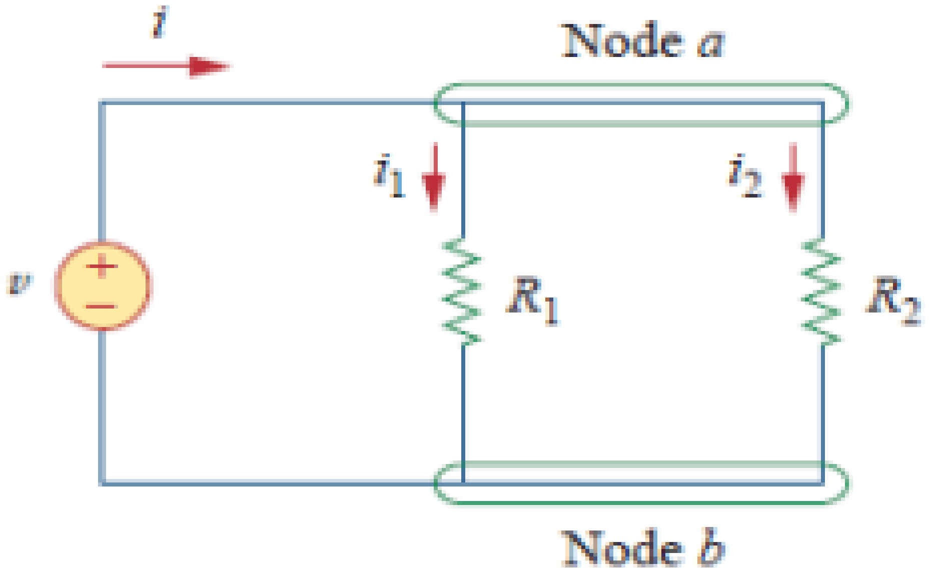


Fig. 5: A single-loop circuit with two resistors in parallel.

❑ 2.3 Series and parallel resistance

- Note that the equivalent resistance is always smaller than the resistance of the smallest resistor in the parallel combination. If

$$R1 = R2 = \cdots = RN = R, \text{ then}$$

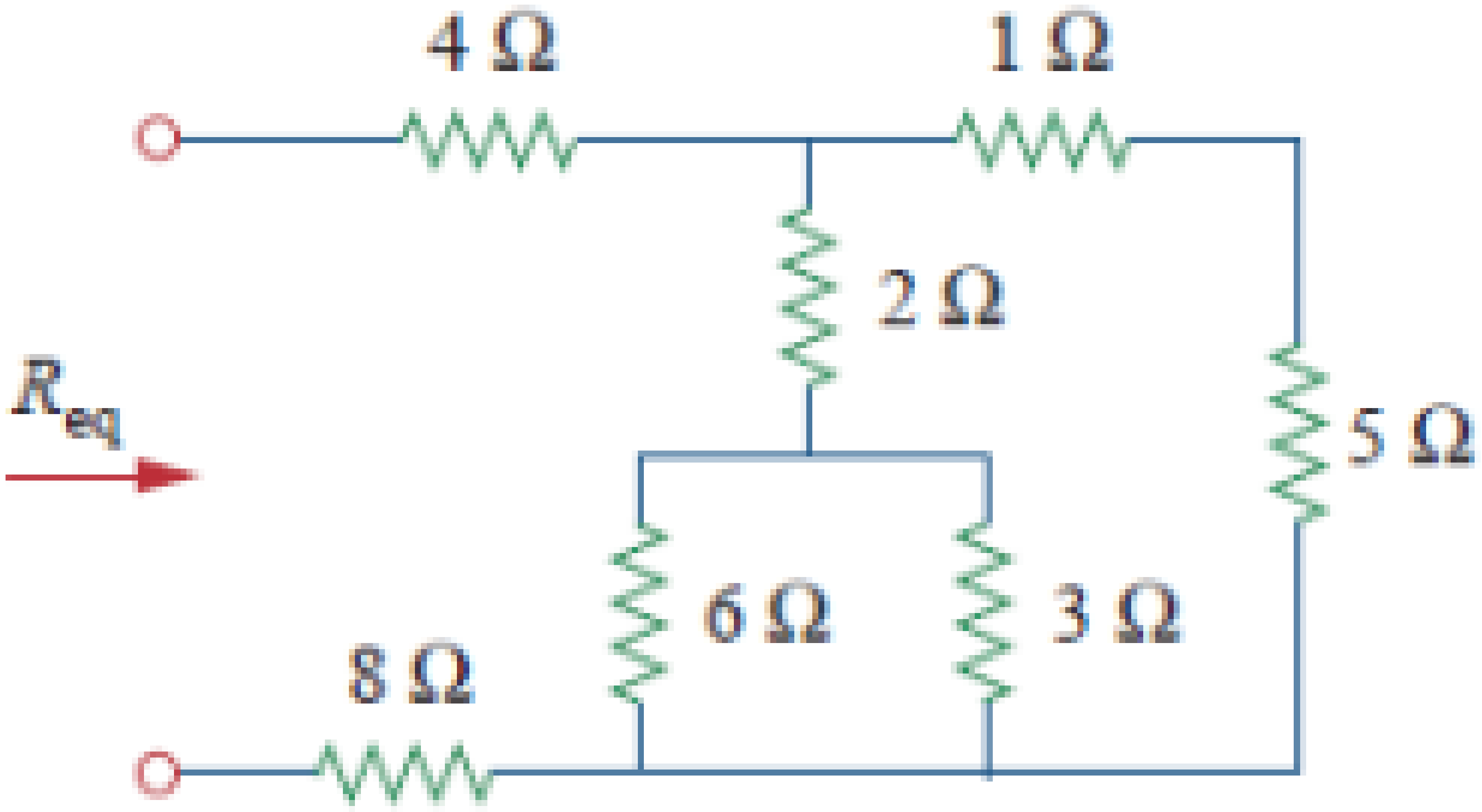
$$R_{eq} = \frac{R}{N}$$

- The equivalent conductance of resistors connected in parallel is the sum of their individual conductance.

$$Geq = G1 + G2 + \cdots + GN$$

❑ Example 2.2:

➢ Find Req for the circuit shown in the following figure



❑ Example 2.2:

Answer:

Two resistors 6 and 3 parallel

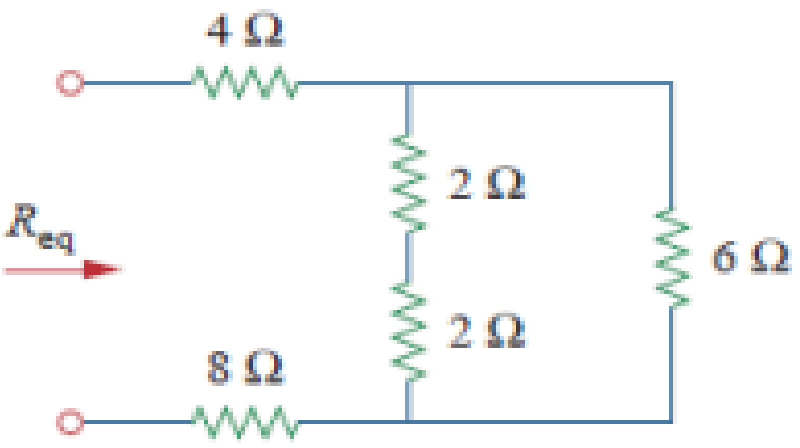
6 // 3 = 2 Ω

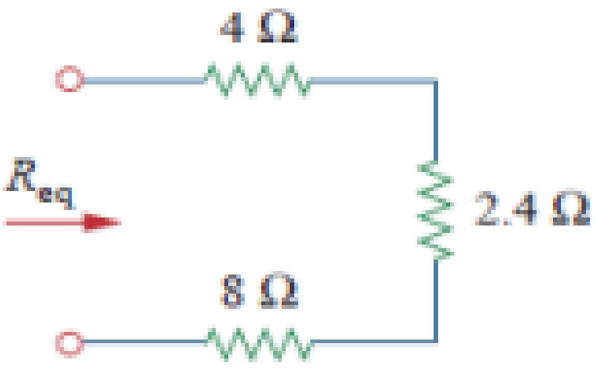
Two resistors 2 and 2 series and parallel with 6

(2+2) // 6 = 2.4 Ω

Three resistances 4, 8 and 2.4 are series

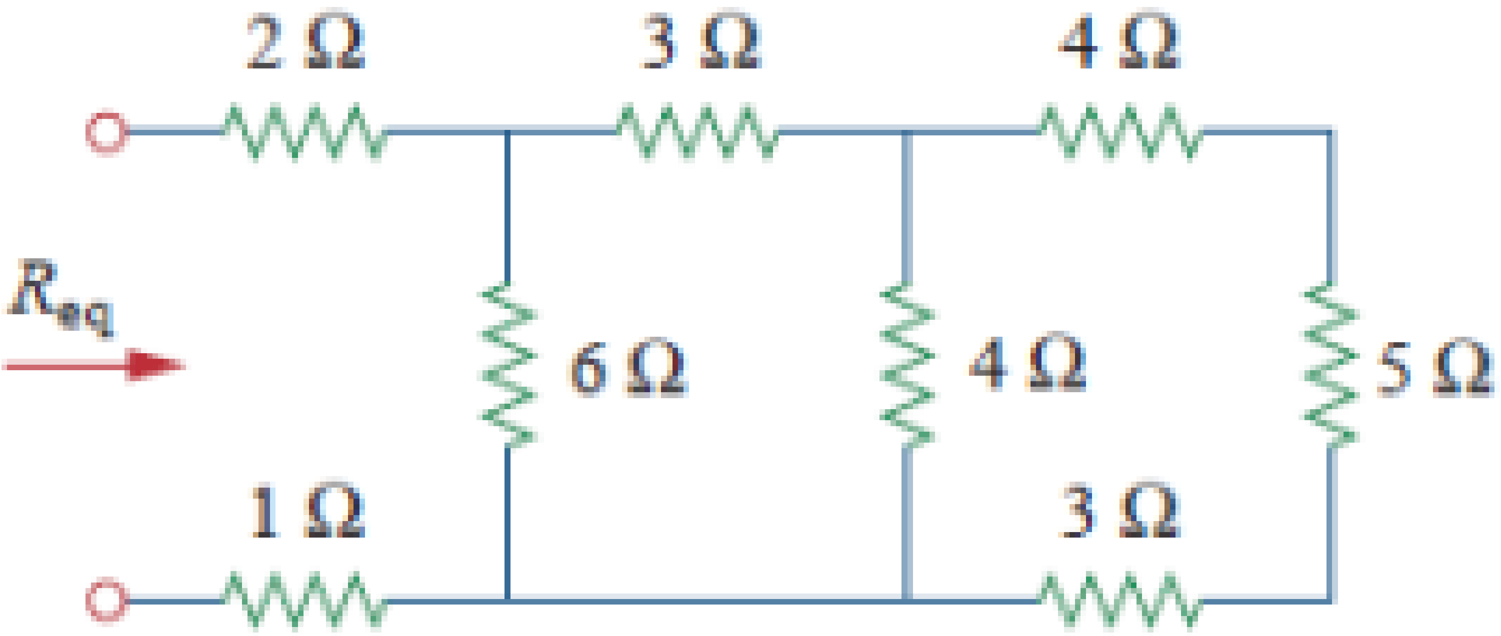
4 + 8 + 2.4 = 14.4 Ω





❑ Example 2.3:

- Find Req for the circuit shown in the following figure



Answer: 6 Ω.

❑ 2.4 Voltage and current division

- To determine the voltage across each resistor by using voltage divider in figure 4 as the following

$$v_1 = \frac{R_1}{(R_1 + R_2)} v \qquad v_2 = \frac{R_2}{(R_1 + R_2)} v$$

$$v_i = \frac{R_i}{(R_1 + R_2 + \cdots + R_N)} v$$

❑ 2.4 Voltage and current division

- To determine the current through each resistor by using current divider in figure 5 as the following

$$v = iR_{eq} = \frac{iR_1R_2}{(R_1 + R_2)} = i_1R_1 = i_2R_2$$

$$i_1 = \frac{R_2}{(R_1 + R_2)} i$$

$$i_2 = \frac{R_1}{(R_1 + R_2)} i$$


Thank
you