电子科技大学格拉斯哥学院
Glasgow College, UESTC

Circuit Analysis and Design

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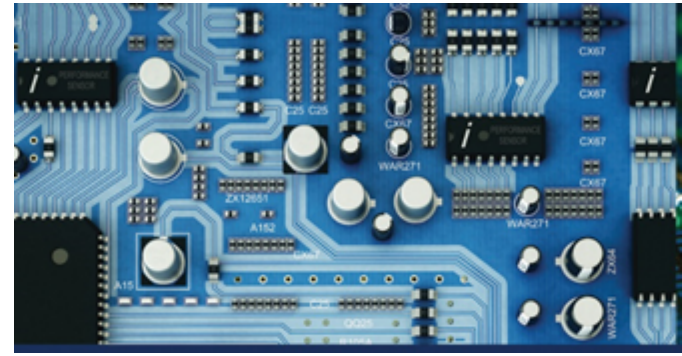
"A good student never steal or cheat"

Agenda



- Review of previous lecture
- Equivalent resistance of parallel connection of resistors
- Solving circuit problems using KCL, KVL, and equivalent resistances
- Voltage divider rule and current divider rule
- Summary

Equivalent Resistance of Parallel Connection of Two Resistors

- Two resistors R_1 and R_2 are connected in parallel as shown in Figure 2.34(a).
- I_1 = current through R_1, I_2 = current through R_2, V = voltage across R_1 and R_2
- KCL:

$$I = I_1 + I_2 = \frac{V}{R_1} + \frac{V}{R_2} = \left(\frac{1}{R_1} + \frac{1}{R_2}\right)V \Rightarrow V = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2}} I = R_{eq} I$$

- The equivalent resistance

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

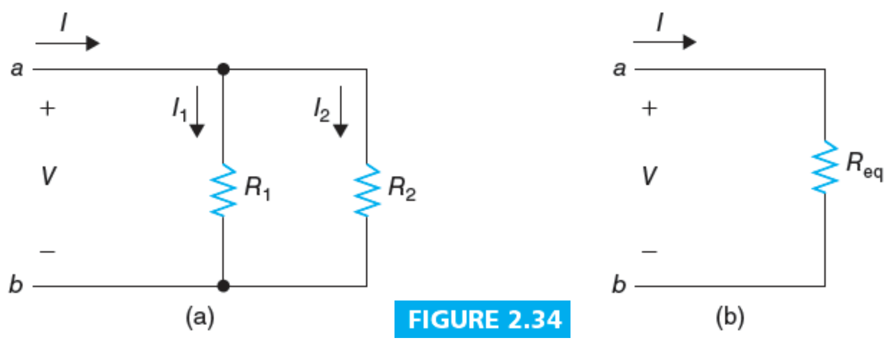


FIGURE 2.34

- The circuit shown in Figure 2.34(a) can be replaced by the equivalent circuit shown in Figure 2.34(b).

Properties of $R_{eq} = R_1 \parallel R_2$

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

- $R_{eq} < R_1$, $R_{eq} < R_2$
  The equivalent resistance is smaller than the smaller of the two.
- $R_1 \parallel 0 = 0$, $R_1 \parallel \infty = R_1$.
- If $R_1 << R_2$, $R_1 \parallel R_2 \approx R_1$.
- If $R_1 = R_2 = R$, $R_1 \parallel R_2 = R \parallel R = R/2$.

Equivalent Resistance of Parallel Connection of n Resistors

- n resistors R_1, R_2, …, R_n are connected in parallel as shown in Figure 2.35(a).
- I_1 = current through R_1, I_2 = current through R_2, …, I_n = current through R_n
- V = voltage across R_1, R_2, …, R_n, equivalent circuit in Figure 2.35(b).
- KCL

$$I = I_1 + I_2 + \ldots + I_n = \frac{V}{R_1} + \frac{V}{R_2} + \ldots + \frac{V}{R_n} = \left(\frac{1}{R_1} + \frac{1}{R_2} + \ldots + \frac{1}{R_n} \right) V$$

$$V = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \ldots + \frac{1}{R_n}} I = R_{eq} I$$

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

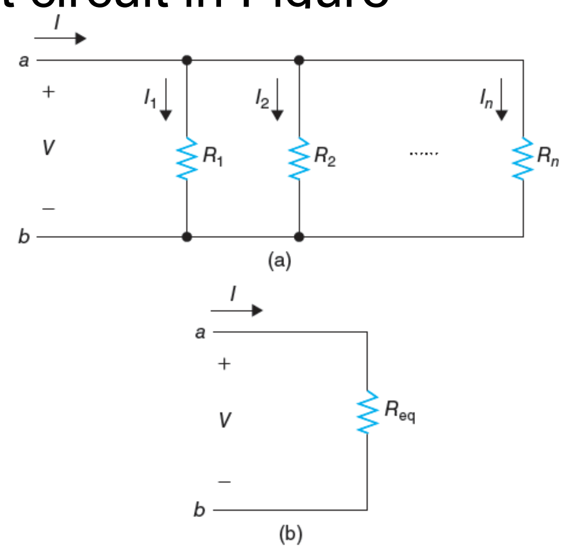


FIGURE 2.35

Circuit with Parallel Connection of Resistors

- Find I_1, V_1, V_2, I_2, I_3, V_3, I_4, I_5, and I_6 in the circuit shown in Figure 2.36.

$$R_a = R_2 \parallel R_3 = \frac{R_2 \times R_3}{R_2 + R_3} = \frac{21k\Omega \times 28k\Omega}{21k\Omega + 28k\Omega} = \frac{588}{49} k\Omega = 12k\Omega$$

$$R_b = R_4 \parallel R_5 \parallel R_6 = \frac{1}{\frac{1}{33} + \frac{1}{40} + \frac{1}{88}} k\Omega = \frac{1}{0.06667} k\Omega = 15k\Omega$$

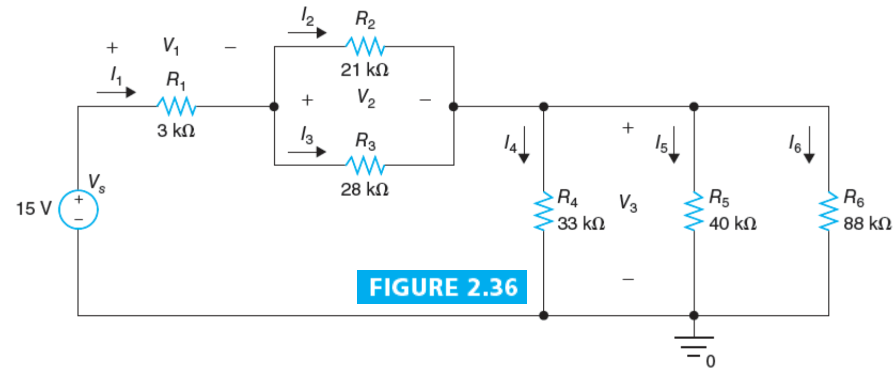


FIGURE 2.36

- The circuit reduces to the one in Figure 2.37. The current I_1 i

$$I_1 = \frac{V_s}{R_1 + R_a + R_b} = \frac{15\,\text{V}}{30\,k\Omega} = 0.5\,\text{mA}$$

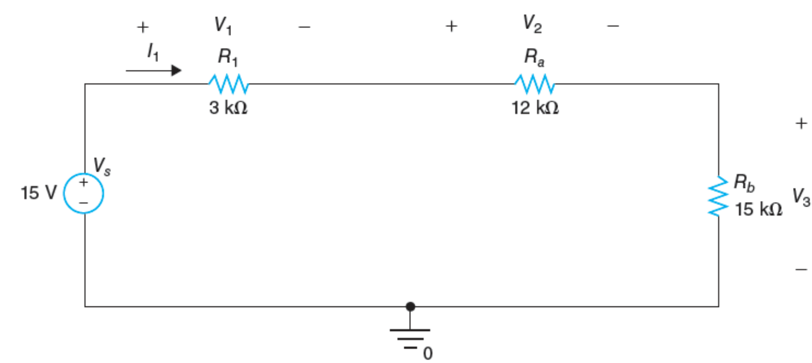


FIGURE 2.37

- $V_1 = R_1 I_1 = 1.5$ V, $V_2 = R_a I_1 = 6$ V,
  $V_3 = R_b I_1 = 7.5$ V, $I_2 = V_2/R_2 = 0.2857$
  $I_3 = V_2/R_3 = 0.2143$ mA, $I_4 = V_3/R_4 = 0.2273$mA,
  $I_5 = V_3/R_5 = 0.1875$ mA, $I_6 = V_3/R_6 = 0.08523$ mA

EXAMPLE 2.11

- Find the equivalent resistance between terminals *a* and *b* for the circuit shown in Figure 2.38.

$$R_6 = R_4 \parallel R_5 = \frac{50 \times 75}{50 + 75} k\Omega = 30\, k\Omega$$

- $R_7 = R_3 + R_6 = 60\ k\Omega$

$$R_{eq} = \frac{1}{\dfrac{1}{R_1} + \dfrac{1}{R_2} + \dfrac{1}{R_7}} = \frac{1}{\dfrac{1}{45} + \dfrac{1}{90} + \dfrac{1}{60}} k\Omega = 20\, k\Omega$$

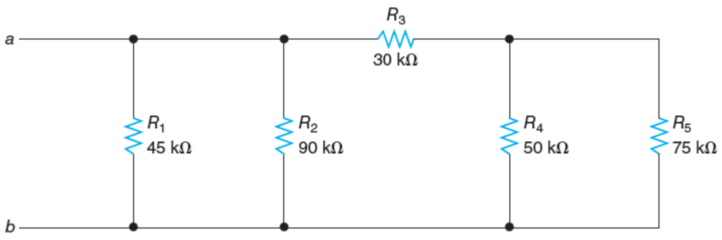


FIGURE 2.38

EXAMPLE 2.12

- Find the equivalent resistance seen from the voltage source. Also find I, I_1, I_2, V_1, V_2, V_3, and power absorbed by resistors and power released by the voltage source.
- $R_a = R_3 \parallel R_4 = R_3 \times R_4/(R_3+R_4) = 100/25\ \mathrm{k\Omega} = 4\ \mathrm{k\Omega}$, $R_{eq} = R_1 + R_2 + R_a = 9\ \mathrm{k\Omega}$
- $I = V_s/R_{eq} = 9/9000\ \mathrm{A} = 1\ \mathrm{mA}$
- $V_1 = R_1 I = 2\ \mathrm{V}$, $V_2 = R_2 I = 3\ \mathrm{V}$, $V_3 = R_a I = 4\ \mathrm{V}$
- $I_1 = V_3/R_3 = 0.8\ \mathrm{mA}$, $I_2 = V_3/R_4 = 0.2\ \mathrm{mA}$
- $P_{R1} = IV_1 = 2\ \mathrm{mW}$, $P_{R2} = IV_2 = 3\ \mathrm{mW}$, $P_{R3} = I_1 V_3 = 3.2\ \mathrm{mW}$, $P_{R4} = I_2 V_3 = 0.8\ \mathrm{mW}$
- $P_{Vs} = -IV_s = -9\ \mathrm{mW}$
- Power absorbed by resistors = 9 mW
- Power released by voltage source = 9 mW

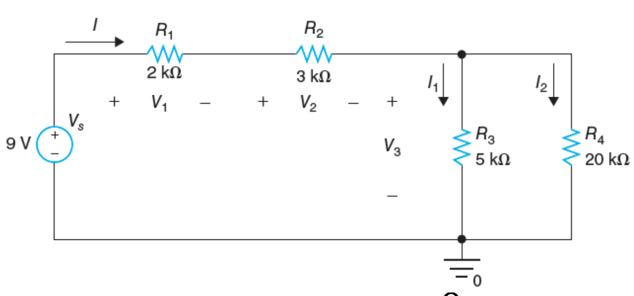


FIGURE 2.40

EXAMPLE 2.13

- Find R_{eq} seen from the voltage source in the circuit shown in Fig.2.43. Also find I_1, I_2, I_3, I_4, I_5, V_1, V_2, V_3, and power absorbed by resistors and power released by the voltage source.
- $R_a = R_4 \parallel R_5 = R_4 \times R_5/(R_4+R_5) = 24/10\ k\Omega = 2.4\ k\Omega$, $R_b = R_3 + R_a = 4\ k\Omega$
- $R_c = R_2 \parallel R_b = R_2 \times R_b/(R_2+R_b) = 64/20\ k\Omega = 3.2\ k\Omega$, $R_{eq} = R_1 + R_c = 5\ k\Omega$
- $I_1 = V_s/R_{eq} = 10/5000\ A = 2\ mA$, $V_1 = V_s - R_1 I_1 = 6.4\ V$, $I_2 = V_1/R_2 = 6.4/16000\ A = 0.4\ mA$
- $I_3 = I_1 - I_2 = 1.6\ mA$, $V_2 = V_1 - R_3 I_3 = 3.84\ V$, $I_4 = V_2/R_4 = 3.84/4000\ A = 0.96\ mA$, $V_{R5} = V_3$
- $I_5 = V_2/R_5 = 3.84/6000\ A = 0.64\ mA$, $V_{R1} = R_1 I_1 = 3.6\ V$, $V_{R3} = R_3 I_3 = 2.56\ V$, $V_{R2} = V_1$, $V_{R4} = V_3$
- $P_{R1} = I_1 V_{R1} = 7.2\ mW$, $P_{R3} = I_3 V_{R3} = 4.096\ mW$, $P_{R2} = I_2 V_{R2} = 2.56\ mW$
- $P_{R4} = I_4 V_{R4} = 3.6864\ mW$
- $P_{R5} = I_5 V_{R5} = 2.4576\ mW$
- $P_{Vs} = -I_1 V_s = -20\ mW$, Power released = 20 mW
- Power absorbed by five resistors = 20 mW

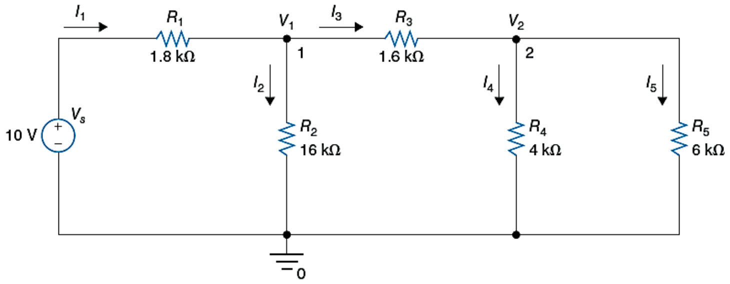


FIGURE 2.43

EXAMPLE 2.14

- Find the equivalent resistance seen from the current source. Also find I_a, I_1, I_2, I_3, I_4, I_5, I_6, I_7, V_1, V_2, V_3 for the circuit shown in Figure 2.46.
- $R_8 = R_1 \parallel R_2 = R_1 \times R_2/(R_1+R_2) = 1200/80\ \text{k}\Omega = 15\ \text{k}\Omega$, $R_9 = R_3 + R_8 = 20\ \text{k}\Omega$
- $R_a = R_4 \parallel R_9 = R_4 \times R_9/(R_4+R_9) = 600/50\ \text{k}\Omega = 12\ \text{k}\Omega$
- $R_{10} = R_6 \parallel R_7 = R_6 \times R_7/(R_6+R_7) = 960/64\ \text{k}\Omega = 15\ \text{k}\Omega$, $R_b = R_5 + R_{10} = 36\ \text{k}\Omega$
- $R_{eq} = R_a \parallel R_b = R_a \times R_b/(R_a+R_b) = 432/48\ \text{k}\Omega = 9\ \text{k}\Omega$
- $V_1 = R_{eq} I_s = 9000 \times 0.002 = 18$ V, $I_a = V_1/R_a = 18/12000$ A $= 1.5$ mA, $I_5 = I_s - I_a = 0.5$ mA
- $I_4 = V_1/R_4 = 18/30000$ A $= 0.6$ mA, $I_3 = I_a - I_4 = 0.9$ mA, $V_2 = V_1 - R_3 I_3 = 13.5$ V
- $I_1 = V_2/R_1 = 0.675$ mA
- $I_2 = V_2/R_2 = 0.225$ mA
- $V_3 = V_1 - R_5 I_5 = 7.5$ V
- $I_6 = V_3/R_6 = 0.3125$ mA
- $I_7 = V_3/R_7 = 0.1875$ mA

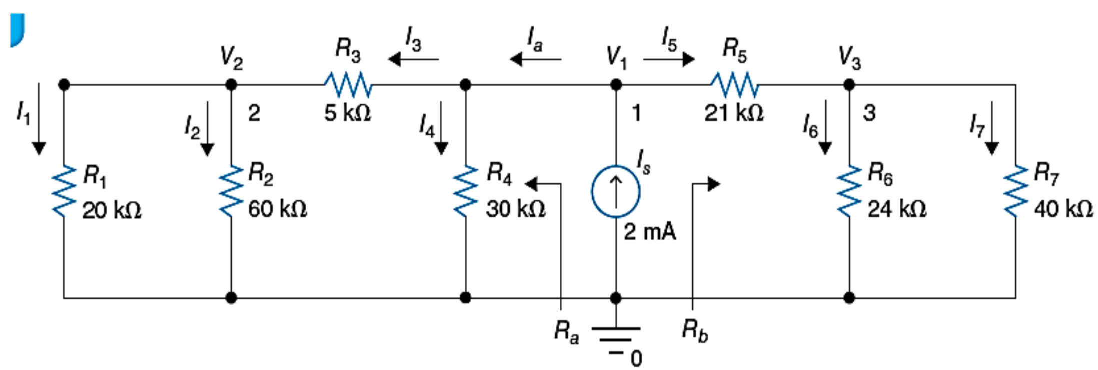


FIGURE 2.46

Voltage Divider Rule for Two Resistors

- A voltage source is connected to a series connection of resistors R_1 and R_2 as shown in Figure 2.49.
- The current through the resistors is given by

$$I = \frac{V_s}{R_1 + R_2}$$

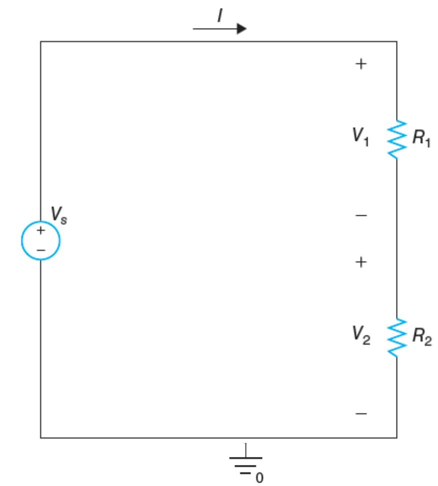
- The voltage across R_1 is given by

$$V_1 = I \times R_1 = \frac{V_s}{R_1 + R_2} \times R_1 = V_s \times \frac{R_1}{R_1 + R_2}$$

- The voltage across R_2 is given by

$$V_2 = I \times R_2 = \frac{V_s}{R_1 + R_2} \times R_2 = V_s \times \frac{R_2}{R_1 + R_2}$$

FIGURE 2.49



- The voltage from the voltage source is divided between R_1 and R_2
  in proportion to the resistance values.

Voltage Divider Rule for n Resistors

- A voltage source is connected to a series connection of n resistors R_1, R_2, …, R_n.
- The current through the resistors is given by

$$I = \frac{V_s}{R_1 + R_2 + \ldots + R_n} \qquad I = \frac{V_s}{R_1 + R_2 + \ldots + R_n}$$

- The voltage across R_i is given by

$$V_i = I \times R_i = \frac{V_s}{R_1 + R_2 + \ldots + R_n} \times R_i = V_s \times \frac{R_i}{R_1 + R_2 + \ldots + R_n}$$

- The voltage from the voltage source is divided among n resistors in proportion to the resistance values.

Circuit Analysis Using Voltage Divider Rule

- We are interested in finding V_1, V_2, and V_3.
- $R_a = R_1 \parallel R_2 = R_1 \times R_2/(R_1+R_2) = 6/5\ \mathrm{k}\Omega = 1.2\ \mathrm{k}\Omega$
- $R_b = R_3 \parallel R_4 = R_3 \times R_4/(R_3+R_4) = 12/8\ \mathrm{k}\Omega = 1.5\ \mathrm{k}\Omega$
- $R_c = R_5 \parallel R_6 = R_5 \times R_6/(R_5+R_6) = 23.805/10.35\ \mathrm{k}\Omega = 2.3\ \mathrm{k}\Omega$

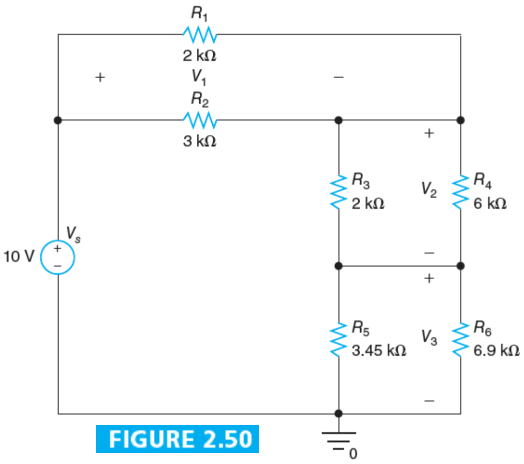


FIGURE 2.50

$$V_1 = V_s \times \frac{R_a}{R_a + R_b + R_c} = 10 \times \frac{1.2}{1.2 + 1.5 + 2.3}\,\mathrm{V} = 10 \times \frac{1.2}{5}\,\mathrm{V} = 2.4\,\mathrm{V}$$

$$V_2 = V_s \times \frac{R_b}{R_a + R_b + R_c} = 10 \times \frac{1.5}{1.2 + 1.5 + 2.3}\,\mathrm{V} = 10 \times \frac{1.5}{5}\,\mathrm{V} = 3\,\mathrm{V}$$

$$V_3 = V_s \times \frac{R_c}{R_a + R_b + R_c} = 10 \times \frac{2.3}{1.2 + 1.5 + 2.3}\,\mathrm{V} = 10 \times \frac{2.3}{5}\,\mathrm{V} = 4.6\,\mathrm{V}$$

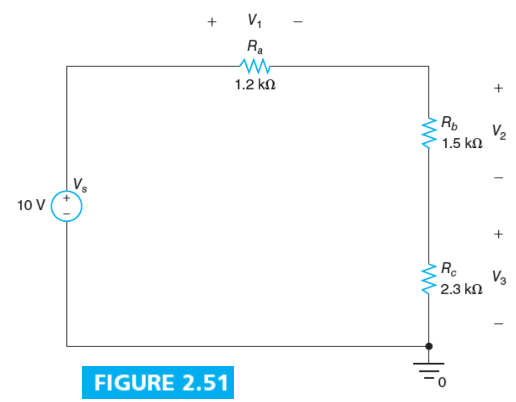


FIGURE 2.51

EXAMPLE 2.15

- Find V_1, V_2, and V_3 in the circuit shown in Figure 2.52.
- $R_a = R_2 \parallel R_3 = R_2 \times R_3/(R_2+R_3) = 24/10\ \text{k}\Omega = 2.4\ \text{k}\Omega$

$$V_1 = V_s \times \frac{R_1}{R_1 + R_a + R_4} = 14 \times \frac{1.2}{1.2+2.4+3.4}\,\text{V} = 14 \times \frac{1.2}{7}\,\text{V} = 2.4\,\text{V}$$

$$V_2 = V_s \times \frac{R_a}{R_1 + R_a + R_4} = 14 \times \frac{2.4}{1.2+2.4+3.4}\,\text{V} = 14 \times \frac{2.4}{7}\,\text{V} = 4.8\,\text{V}$$

$$V_3 = V_s \times \frac{R_4}{R_1 + R_a + R_4} = 14 \times \frac{3.4}{1.2+2.4+3.4}\,\text{V} = 14 \times \frac{3.4}{7}\,\text{V} = 6.8\,\text{V}$$

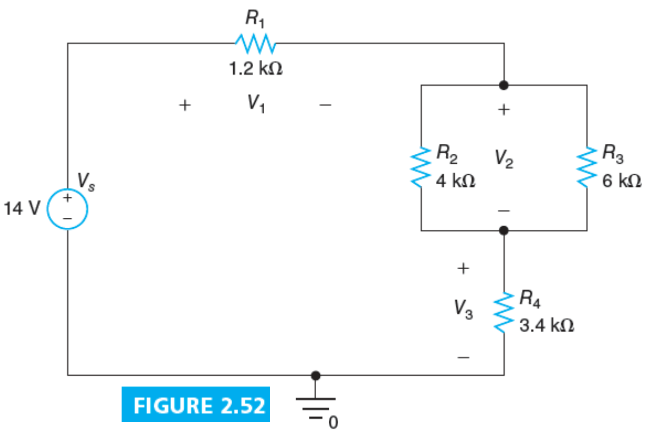


FIGURE 2.52

EXAMPLE 2.16

- Find V_1, V_2, and V_3 in the circuit shown in Figure 2.54.
- $R_a = R_1 \,||\, (R_2+R_3) = 28\times52/(28+52)$ kΩ = 18.2 kΩ
- $R_b = R_4 \,||\, (R_5+R_6) = 38\times57/(38+57)$ kΩ = 22.8 kΩ

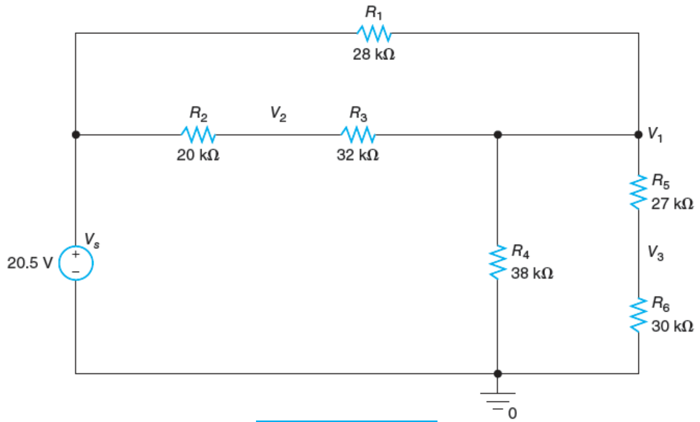


FIGURE 2.54

$$V_1 = V_s \times \frac{R_b}{R_a + R_b} = 20.5\times\frac{22.8}{18.2+22.8}\,\mathrm{V} = 20.5\times\frac{22.8}{41}\,\mathrm{V} = 11.4\,\mathrm{V}$$

$$V_2 = V_1 + \left(V_s - V_1\right)\times\frac{R_3}{R_2+R_3} = 11.4\,\mathrm{V} + 9.1\times\frac{32}{20+32}\,\mathrm{V} = 11.4\,\mathrm{V} + 5.6\,\mathrm{V} = 17\,\mathrm{V}$$

$$V_3 = V_1 \times \frac{R_6}{R_5+R_6} = 11.4\times\frac{30}{27+30}\,\mathrm{V} = 6\,\mathrm{V}$$

Current Divider Rule for Two Resistors in Parallel

- Two resistors are connected in parallel to a current source (Fig.2.58).

The equivalent resistance of R_1 and R_2 is given by

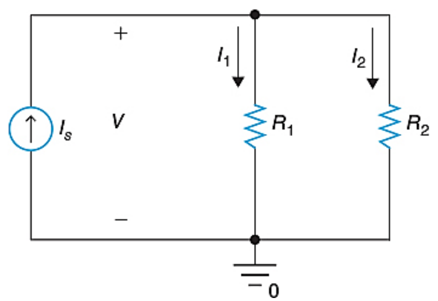
$$R = R_1 \parallel R_2 = \frac{1}{\frac{1}{R_1}+\frac{1}{R_2}}$$

The voltage across R_1 and R_2 is given by

$$V = I_s R = I_s \times \frac{1}{\frac{1}{R_1}+\frac{1}{R_2}}$$

FIGURE 2.58

A circuit with two resistors in parallel.



- The current through R_1 and R_2 are given respectively by

$$I_1 = \frac{V}{R_1} = I_s \times \frac{\frac{1}{R_1}}{\frac{1}{R_1}+\frac{1}{R_2}} = I_s \times \frac{G_1}{G_1+G_2} = I_s \times \frac{R_2}{R_1+R_2}, \quad I_2 = \frac{V}{R_2} = I_s \times \frac{\frac{1}{R_2}}{\frac{1}{R_1}+\frac{1}{R_2}} = I_s \times \frac{G_2}{G_1+G_2} = I_s \times \frac{R_1}{R_1+R_2}$$

- The current I_s from the current source is divided between R_1 and R_2 in proportion to the conductance (inverse of resistance) value. More current flows through smaller resistance.

Current Divider Rule for n Resistors in Parallel

- n resistors are connected in parallel to a current source with current I_s.
- The equivalent resistance is given by

$$R = R_1 \| R_2 \| \ldots \| R_n = \frac{1}{\dfrac{1}{R_1} + \dfrac{1}{R_2} + \ldots + \dfrac{1}{R_n}}$$

- The voltage across the resistors is given by $V = I_s R = I_s \times \dfrac{1}{\dfrac{1}{R_1} + \dfrac{1}{R_2} + \ldots + \dfrac{1}{R_n}}$
- The current through the *i*th resistor R_i is

$$I_i = \frac{V}{R_i} = I_s \times \frac{\dfrac{1}{R_i}}{\dfrac{1}{R_1} + \dfrac{1}{R_2} + \ldots + \dfrac{1}{R_n}} = I_s \times \frac{G_i}{G_1 + G_2 + \ldots + G_n}$$

- The current I_s from the current source is divided between resistors in proportion to the conductance (inverse of resistance) values.

Circuit Analysis Using Current Divider Rule

- Find I_1, I_2, I_3 in the circuit shown in Figure 2.59.
- $R_a = R_3 + (R_1 \parallel R_2) = 0.8\ \text{k}\Omega + 1.2\ \text{k}\Omega = 2\ \text{k}\Omega$
- $R_b = R_7 + (R_5 \parallel R_6) = 2.6\ \text{k}\Omega + 2.4\ \text{k}\Omega = 5\ \text{k}\Omega$

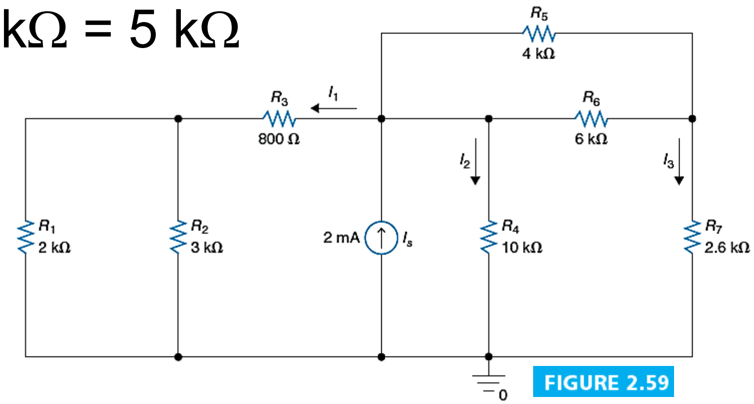


FIGURE 2.59

$$I_1 = I_s \times \frac{\frac{1}{R_a}}{\frac{1}{R_a}+\frac{1}{R_4}+\frac{1}{R_b}} = 2\times\frac{\frac{1}{2}}{\frac{1}{2}+\frac{1}{10}+\frac{1}{5}}\,\text{mA} = 2\times\frac{5}{8}\,\text{mA} = 1.25\,\text{mA}$$

$$I_2 = I_s \times \frac{\frac{1}{R_4}}{\frac{1}{R_a}+\frac{1}{R_4}+\frac{1}{R_b}} = 2\times\frac{\frac{1}{10}}{\frac{1}{2}+\frac{1}{10}+\frac{1}{5}}\,\text{mA} = 2\times\frac{1}{8}\,\text{mA} = 0.25\,\text{mA}$$

$$I_3 = I_s \times \frac{\frac{1}{R_b}}{\frac{1}{R_a}+\frac{1}{R_4}+\frac{1}{R_b}} = 2\times\frac{\frac{1}{5}}{\frac{1}{2}+\frac{1}{10}+\frac{1}{5}}\,\text{mA} = 2\times\frac{2}{8}\,\text{mA} = 0.5\,\text{mA}$$

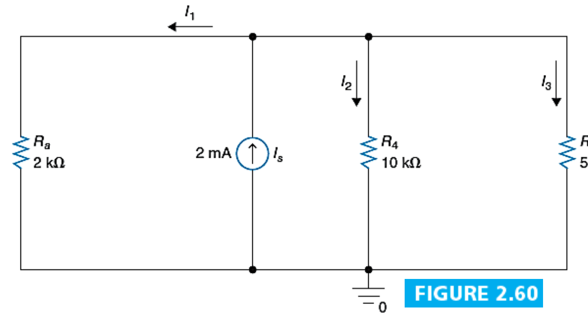


FIGURE 2.60

EXAMPLE 2.17

- In the circuit shown in Fig.2.61, use the current divider rule to find the currents I_1, I_2, I_3, I_4, I_5.

$$I_1 = I_s \times \frac{R_2}{R_1 + R_2} = 22 \times \frac{7}{4+7}\,\text{mA} = 22 \times \frac{7}{11}\,\text{mA} = 14\,\text{mA}$$

$$I_2 = I_s \times \frac{R_1}{R_1 + R_2} = 22 \times \frac{4}{4+7}\,\text{mA} = 22 \times \frac{4}{11}\,\text{mA} = 8\,\text{mA}$$

$$I_3 = I_s \times \frac{\frac{1}{R_3}}{\frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R_5}} = 22 \times \frac{\frac{1}{2}}{\frac{1}{2} + \frac{1}{4} + \frac{1}{6}}\,\text{mA} = 22 \times \frac{6}{11}\,\text{mA} = 12\,\text{mA}$$

$$I_4 = I_s \times \frac{\frac{1}{R_4}}{\frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R_5}} = 22 \times \frac{\frac{1}{4}}{\frac{1}{2} + \frac{1}{4} + \frac{1}{6}}\,\text{mA} = 22 \times \frac{3}{11}\,\text{mA} = 6\,\text{mA}$$

$$I_5 = I_s \times \frac{\frac{1}{R_5}}{\frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R_5}} = 22 \times \frac{\frac{1}{6}}{\frac{1}{2} + \frac{1}{4} + \frac{1}{6}}\,\text{mA} = 22 \times \frac{2}{11}\,\text{mA} = 4\,\text{mA}$$

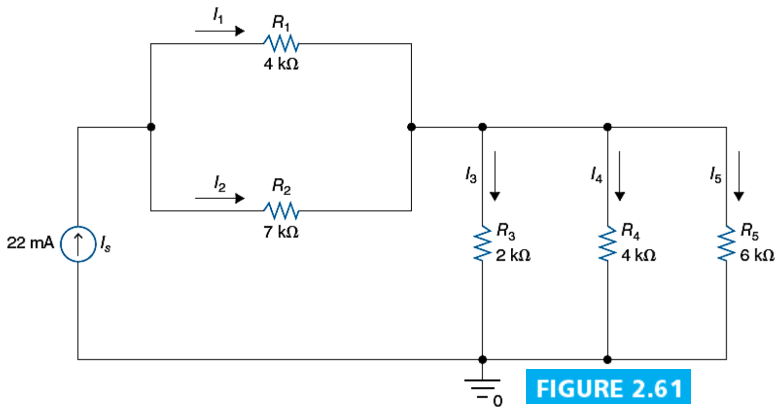


FIGURE 2.61

EXAMPLE 2.18

- Find I_1, I_2, I_3, I_4, I_5, I_6, I_7, I_8, I_9 in the circuit shown in Figure 2.63.
- $R_a = R_2 + (R_3 \parallel R_4) = 3\ k\Omega$
- $R_b = (R_5 \parallel R_6) + (R_7 \parallel R_8) = 3\ k\Omega + 2\ k\Omega = 5\ k\Omega$
- Application of current divider rule on R_1, R_a, R_b, we obtain

$$I_1 = I_s \times \frac{\frac{1}{R_1}}{\frac{1}{R_1}+\frac{1}{R_a}+\frac{1}{R_b}} = 10 \times \frac{\frac{1}{7.5}}{\frac{1}{7.5}+\frac{1}{3}+\frac{1}{5}}\ \mathrm{mA} = 10 \times \frac{2}{10}\ \mathrm{mA} = 2\ \mathrm{mA}$$

$$I_2 = I_s \times \frac{\frac{1}{R_a}}{\frac{1}{R_1}+\frac{1}{R_a}+\frac{1}{R_b}} = 10 \times \frac{\frac{1}{3}}{\frac{1}{7.5}+\frac{1}{3}+\frac{1}{5}}\ \mathrm{mA} = 10 \times \frac{5}{10}\ \mathrm{mA} = 5\ \mathrm{mA}$$

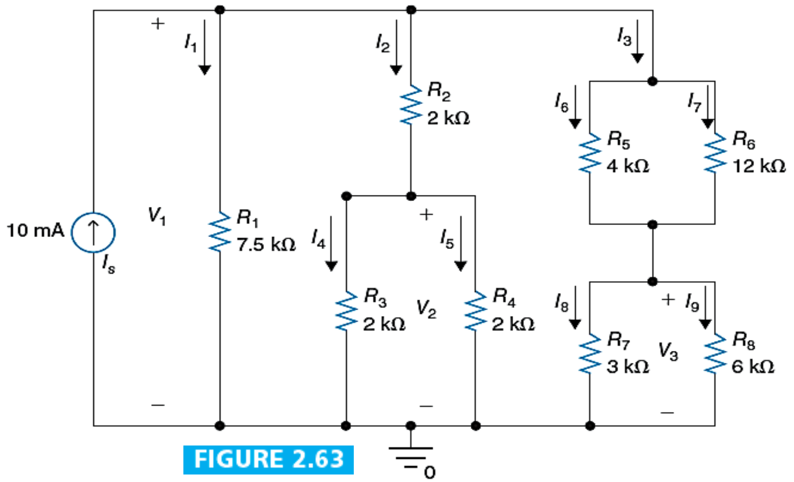


FIGURE 2.63

EXAMPLE 2.18 (Continued)

$$I_3 = I_s \times \frac{\frac{1}{R_b}}{\frac{1}{R_1} + \frac{1}{R_a} + \frac{1}{R_b}} = 10 \times \frac{\frac{1}{5}}{\frac{1}{7.5} + \frac{1}{3} + \frac{1}{5}} \text{mA} = 10 \times \frac{3}{10} \text{mA} = 3\,\text{mA}$$

$$I_4 = I_2 \times \frac{R_4}{R_3 + R_4} = 2.5\,\text{mA} = I_5$$

$$I_6 = I_3 \times \frac{R_6}{R_5 + R_6} = 2.25\,\text{mA},\ I_7 = 0.75\,\text{mA}$$

$$I_8 = I_3 \times \frac{R_8}{R_7 + R_8} = 2\,\text{mA},\ \ I_9 = 1\,\text{mA}$$

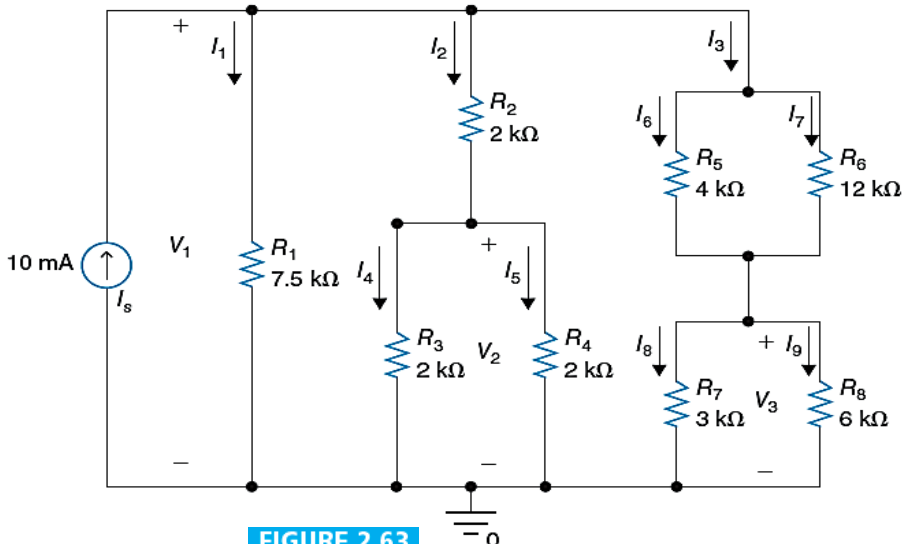


FIGURE 2.63

Summary of key concepts weeks 2-3

- **Resistance** (definition and physical meaning)

$$R = \frac{\ell}{\sigma A} = \frac{\ell \rho}{A}$$

- **Ohm**'s law

$$V = RI, \quad I = \frac{V}{R}, \quad R = \frac{V}{I}$$

- **KCL**

The sum of currents entering a node equals the sum of currents leaving the same <u>node</u>.
The sum of currents leaving a node is zero.
The sum of currents entering a node is zero.

Summary (Continued)

- **KVL**

  The sum of voltage drops around a loop or mesh is equal to zero.

- **Equivalent resistance of series** connection of n resistors

$$R_{eq} = R_1 + R_2 + \ldots + R_n$$

- **Equivalent resistance of parallel** connection of two resistors

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

Summary (Continued)

- Equivalent resistance of parallel connection of n resistors

$$R_{eq} = R_1 \parallel R_2 \parallel \ldots \parallel R_n = \frac{1}{\dfrac{1}{R_1} + \dfrac{1}{R_2} + \ldots + \dfrac{1}{R_n}}$$

- **Voltage divider** rule (two resistors are connected in series to a voltage source)

$$V_1 = V_s \times \frac{R_1}{R_1 + R_2}, \quad V_2 = V_s \times \frac{R_2}{R_1 + R_2}$$

- **Voltage divider rule** (n resistors are connected in series to a voltage source)

$$V_i = V_s \times \frac{R_i}{R_1 + R_2 + \ldots + R_n}$$

Summary (Continued)

- **Current divider** rule (two resistors are connected in parallel to a current source)

$$I_1 = I_s \times \frac{\frac{1}{R_1}}{\frac{1}{R_1} + \frac{1}{R_2}} = I_s \times \frac{R_2}{R_1 + R_2}, \quad I_2 = I_s \times \frac{\frac{1}{R_2}}{\frac{1}{R_1} + \frac{1}{R_2}} = I_s \times \frac{R_1}{R_1 + R_2}$$

- **Current divider** rule (n resistors are connected in parallel to a current source)

$$I_i = I_s \times \frac{\frac{1}{R_i}}{\frac{1}{R_1} + \frac{1}{R_2} + \ldots + \frac{1}{R_n}}$$

Summary (Continued)

- **What will we study in next lecture.**