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DC Electrical Circuits Analysis

Practice Problems, Methods, and Solutions

Second Edition

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Basic Concepts and Laws of Electrical Circuits Analysis: Part A

1

Abstract

In this chapter, the problems concerned with the basic concepts and laws of electrical circuits analysis are studied. The subjects include resistance, Ohm's law, equivalent resistance of series, parallel, and series-parallel connections, wye-delta transformation and heuristic methods for equivalent resistance calculation, voltage and current division rules, ideal independent voltage source, ideal independent current source, ideal dependent voltage and current sources, Kirchhoff's current law (KCL), Kirchhoff's voltage law (KVL), and power consumption and generation. Herein, different types of problems and exercises are presented that are categorized as follows.

- ***Problems with detailed solution***: They have been designed to teach students the subjects in detail. Moreover, they have been categorized in different levels based on their difficulty levels (easy, normal, and hard) and calculation amounts (small, normal, and large).
- ***Partially solved exercises***: They have been designed to encourage students to practice problems while guiding them through the problem-solving procedure and hinting the required formulas.
- ***Exercises with final answer***: They have been designed to encourage students to practice more by themselves while hinting them by the final answer as well as to help instructors to give tests or quizzes.

1.1 Resistance

Problem

1.1. The diameter of the circular cross-sectional area, length, and resistance of a wire are 1 mm, 2 m, and 0.1 Ω, respectively. Calculate the special resistance (resistivity) of the wire [1–9].

Difficulty level ● Easy ○ Normal ○ Hard

Calculation amount ● Small ○ Normal ○ Large



1) 3.92×10^{-8} Ωm
2) 1.56×10^{-7} Ωm
3) 3.92×10^{-7} Ωm
4) 1.56×10^{-8} Ωm

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F. X. Malcata, *DC Electrical Circuits Analysis*, https://doi.org/10.1007/978-3-032-00253-2_1

Partially Solved Exercise

1.2. The radius of the circular cross-sectional area, length, and special resistance (resistivity) of a wire are 2 mm, 3 m, and 1.5 Ωm, respectively. Calculate the resistance of the wire.

Solution

As we know, the resistance of a wire can be calculated as follows.

$$R = \rho \frac{l}{A}$$

Herein, ρ, l, and A, are the special resistance (resistivity), length, and cross-sectional area of the wire, respectively.
Thus, for this problem, we can write:

$$R = \rho \frac{l}{\pi r^2}$$

$$\Rightarrow R = (\quad\quad) \times \frac{(\quad)}{\pi(\quad\quad)^2}$$

$$\Rightarrow R = 358 \times 10^3\ \Omega$$

$$\Rightarrow R = 358\ \text{k}\Omega$$

Problem

1.3. Consider two wires. The length of the first one is twice the length of the second wire. Moreover, the diameter of circular cross-sectional area of the first wire is half of the one of the second wire. In addition, the special resistance (resistivity) of the first wire is one-third of the one of the second wire. Calculate the ratio of resistance of the first wire to the second one.

Difficulty level ● Easy ○ Normal ○ Hard
Calculation amount ● Small ○ Normal ○ Large



1) $\frac{1}{6}$
2) 24
3) $\frac{4}{3}$
4) $\frac{8}{3}$

Exercise

1.4. Calculate the ratio of resistance of the second wire to the first one if $l_2 = 2l_1$, $r_2 = 3r_1$, and $\rho_2 = 4.5\rho_1$.

Final Answer

$\frac{R_2}{R_1} = 1$

Note: *Read the "educational support" part of the preface of the textbook.*

1.2 Ohm's Law

Problem

1.5. Calculate the resistance of an electrical device that draws 0.1 A current at 110 V.

Difficulty level ● Easy ○ Normal ○ Hard
Calculation amount ● Small ○ Normal ○ Large



1) 110 Ω
2) 1100 Ω
3) 11 Ω
4) 0.001 Ω

Exercise

1.6. On the catalogue of a vacuum cleaner, 4 A and 120 V are written. What is the equivalent resistance of the vacuum cleaner?

Final Answer

$R = 30\ \Omega$

Note: *Read the "educational support" part of the preface of the textbook.*

Problem

1.7. Calculate the current of a 1 kΩ resistor connected to a 10 V power supply.

Difficulty level ● Easy ○ Normal ○ Hard
Calculation amount ● Small ○ Normal ○ Large



1) 100 A
2) 10000 A
3) 0.01 A
4) 1 A

Exercise

1.8. A 12 Ω, 120 V washing machine is available. What current does it draw from the power outlet?

Final Answer

$I = 10$ A

Note: *Read the "educational support" part of the preface of the textbook.*

Problem

1.9. What voltage will appear across a 15 Ω resistance if it carries 100 mA current?

Difficulty level ● Easy ○ Normal ○ Hard
Calculation amount ● Small ○ Normal ○ Large



1) 150 V
2) 0.006 V
3) 0.15 V
4) 1.5 V

Exercise

1.10. Calculate the nominal voltage of an electrical device that its rated resistance and current are 5 kΩ and 10 mA, respectively.

Final Answer

$V = 50$ V

Note: *Read the "educational support" part of the preface of the textbook.*

1.3 Equivalent Resistance of Series, Parallel, and Series-Parallel Connections

Problem

1.11. In the circuit shown in Fig. 1.1, the resistors are connected in series. Calculate the equivalent resistance of the circuit.

Difficulty level ● Easy ○ Normal ○ Hard
Calculation amount ● Small ○ Normal ○ Large



1) 1 Ω
2) 11 Ω
3) 10 Ω
4) 4 Ω

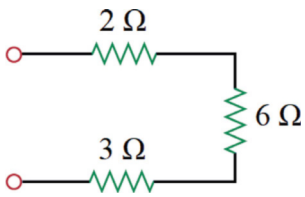


Fig. 1.1 The circuit of problem 1.11

Problem

1.12. In the circuit shown in Fig. 1.2, the resistors are connected in parallel. Calculate the equivalent resistance of the circuit.

Difficulty level ● Easy ○ Normal ○ Hard
Calculation amount ● Small ○ Normal ○ Large



1) 1 Ω
2) 11 Ω
3) 10 Ω
4) 4 Ω

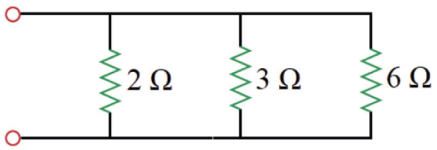


Fig. 1.2 The circuit of problem 1.12

Partially Solved Exercise

1.13. In the circuit of Fig. 1.3, calculate the equivalent resistance seen from the terminal.

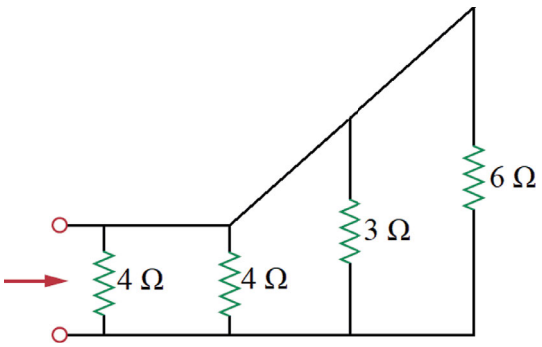


Fig. 1.3 The circuit of partially solved exercise 1.13

Solution

As is shown in Fig. 1.4, the circuit has been simplified. Now, it is noticed that all the resistors are in parallel. Hence:

$$R_{eq} = (4||4)||(3||6)$$

$$\Rightarrow R_{eq} = \left(\frac{(\quad)}{2}\right)||\left(\frac{(\quad)\times(\quad)}{(\quad)+(\quad)}\right)$$

$$\Rightarrow R_{eq} = (\quad)||(\quad)$$

$$\Rightarrow R_{eq} = \frac{(\quad)}{2}$$

$$\Rightarrow R_{eq} = 1\ \Omega$$

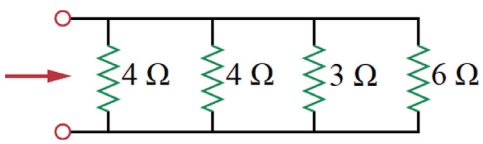


Fig. 1.4 The circuit of partially solved exercise 1.13

Problem

1.14. In the circuit shown in Fig. 1.5, the resistors are connected in series–parallel from. Calculate the equivalent resistance of the circuit.

Difficulty level ● Easy ○ Normal ○ Hard
Calculation amount ● Small ○ Normal ○ Large



1) 4 Ω
2) 1 Ω
3) 0.4 Ω
4) 2.5 Ω

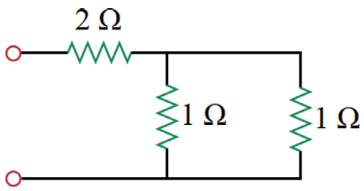


Fig. 1.5 The circuit of problem 1.14

Partially Solved Exercise

1.15. Calculate the equivalent resistance of the circuit shown in Fig. 1.6.

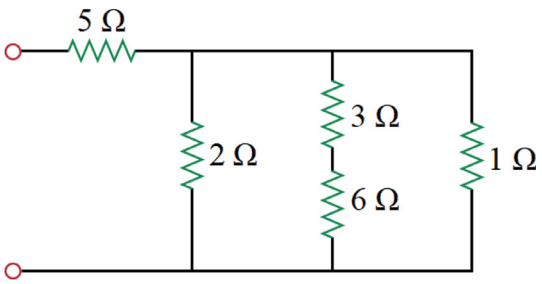


Fig. 1.6 The circuit of partially solved exercise 1.15

Solution

The equivalent resistance of the circuit can be calculated as follows. First, the series connection of the middle branch should be simplified as follows.

$$R_{3,6} = R_3 + R_6 = (\quad) + (\quad) = 9\ \Omega$$

Then, the three parallel branches can be combined as follows.

$$\frac{1}{R_{2,9,1}} = \frac{1}{R_2} + \frac{1}{R_9} + \frac{1}{R_1}$$

$$\Rightarrow \frac{1}{R_{2,9,1}} = \frac{1}{(\quad)} + \frac{1}{(\quad)} + \frac{1}{(\quad)}$$

$$\Rightarrow \frac{1}{R_{2,9,1}} = \frac{(\quad) + (\quad) + (\quad)}{18}$$

$$\Rightarrow R_{2,9,1} = \frac{18}{29}\,\Omega$$

Finally, there are only two resistors connected in series. Thus:

$$R_{eq} = (\quad) + (\quad) = \frac{145 + 18}{29}$$

$$\Rightarrow R_{eq} = \frac{163}{29}\,\Omega$$

Exercise

1.16. Calculate the equivalent resistance of the circuit shown in Fig. 1.7.

Final Answer

$R_{eq} = 14.4\ \Omega$

Note: *Read the "educational support" part of the preface of the textbook.*

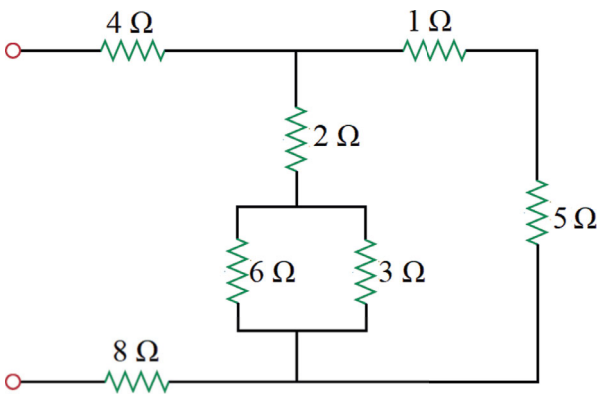


Fig. 1.7 The circuit of exercise 1.16

Problem

1.17. In the circuit of Fig. 1.8, the resistance of each resistor is 1 Ω. Calculate the equivalent resistance seen from the terminal.

Difficulty level ○ Easy ● Normal ○ Hard

Calculation amount ● Small ○ Normal ○ Large



1) 1 Ω
2) 2 Ω
3) 3 Ω
4) 4 Ω

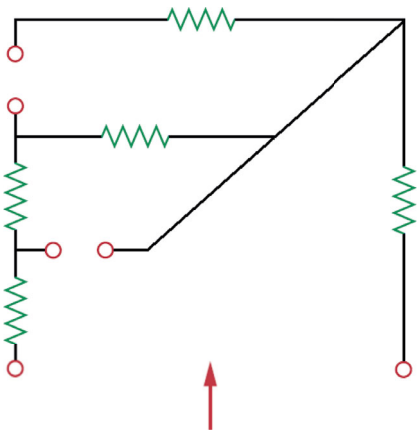


Fig. 1.8 The circuit of problem 1.17

Exercise

1.18. Calculate the equivalent resistance seen from the terminal of the circuit shown in Fig. 1.9. The circuit includes an infinite number of resistors connected in series and the resistance of each of them is one Ohm.

Final Answer

$R_{eq} = \infty$

Note: *Read the "educational support" part of the preface of the textbook.*

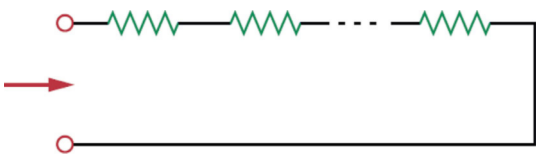


Fig. 1.9 The circuit of exercise 1.18

Exercise

1.19. Calculate the equivalent resistance seen from the terminal of the circuit shown in Fig. 1.10. The circuit includes an infinite number of resistors connected in parallel and the resistance of each of them is 1000 Ω.

Final Answer

$R_{eq} = 0\ \Omega$

Note: *Read the "educational support" part of the preface of the textbook.*

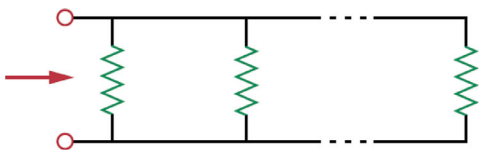


Fig. 1.10 The circuit of exercise 1.19

Problem

1.20. In the circuit of Fig. 1.11, calculate the equivalent resistance seen from the terminal.

Difficulty level ○ Easy ● Normal ○ Hard

Calculation amount ● Small ○ Normal ○ Large



1) 1 Ω
2) 2 Ω
3) 3 Ω
4) 4 Ω

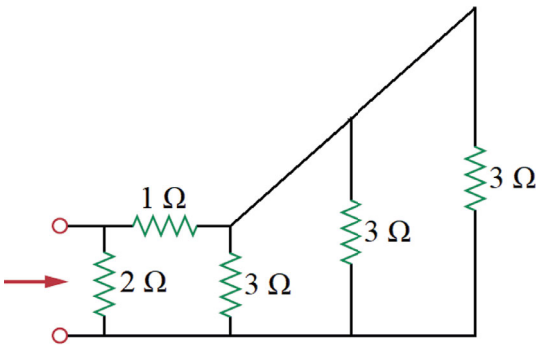


Fig. 1.11 The circuit of problem 1.20

Exercise

1.21. Calculate the equivalent resistance seen from the terminal of the circuit shown in Fig. 1.12. Herein, the resistance of each element is one Ohm.

Final Answer

$R_{eq} = 0.75\ \Omega$

Note: *Read the "educational support" part of the preface of the textbook.*

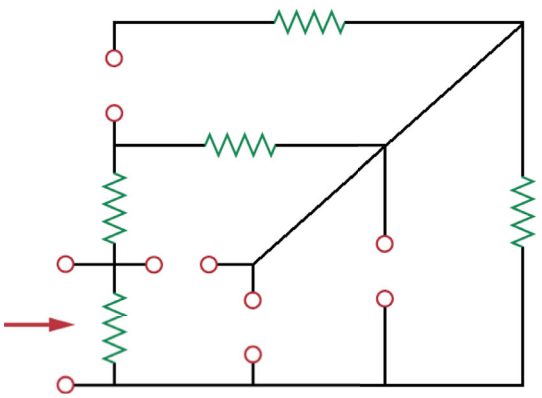


Fig. 1.12 The circuit of exercise 1.21

1.4 Wye-Delta Transformation for Equivalent Resistance Calculation

1.22. In the circuit of Fig. 1.13, calculate the equivalent resistance seen from the terminal.

Difficulty level ○ Easy ● Normal ○ Hard
Calculation amount ○ Small ● Normal ○ Large



1) 8 Ω
2) 28 Ω
3) 20 Ω
4) 12 Ω

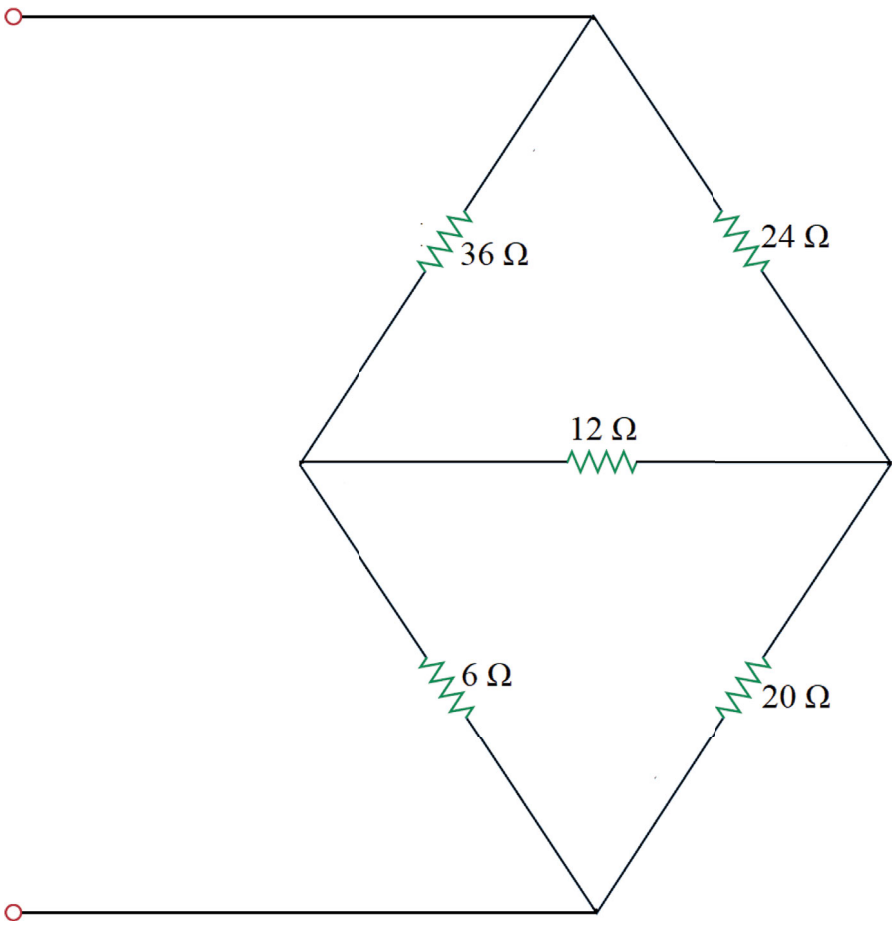


Fig. 1.13 The circuit of problem 1.22

Partially Solved Exercise

1.23. In the circuit shown in Fig. 1.14, we have $R_A = 10\ \Omega$, $R_B = 20\ \Omega$, and $R_C = 40\ \Omega$. Calculate the value of R_{AB}, R_{BC}, and R_{AC}.

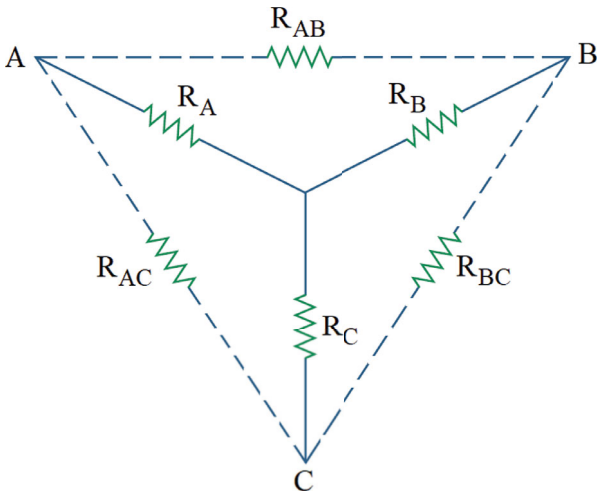


Fig. 1.14 The circuit of partially solved exercise 1.23

Solution

As we know, the relations below are valid when a wye-connection (called Y-connection, T-connection, or star-connection) is converted to a delta-connection (called Δ-connection or π-connection).

$$R_{AB} = \frac{R_A R_B + R_B R_C + R_A R_C}{R_C}$$

$$R_{BC} = \frac{R_A R_B + R_B R_C + R_A R_C}{R_A}$$

$$R_{AC} = \frac{R_A R_B + R_B R_C + R_A R_C}{R_B}$$

Therefore, for this problem, we can write as follows.

$$R_{AB} = \frac{(\quad)(\quad) + (\quad)(\quad) + (\quad)(\quad)}{(\quad)}$$

$$\Rightarrow R_{AB} = 140\ \Omega$$

$$R_{BC} = \frac{(\quad)(\quad) + (\quad)(\quad) + (\quad)(\quad)}{(\quad)}$$

$$\Rightarrow R_{BC} = 70\ \Omega$$

$$R_{AC} = \frac{(\quad)(\quad) + (\quad)(\quad) + (\quad)(\quad)}{(\quad)}$$

$$\Rightarrow R_{AC} = 35\ \Omega$$

Partially Solved Exercise

1.24. In the circuit shown in Fig. 1.15, we have $R_{AB} = 25\ \Omega$, $R_{BC} = 15\ \Omega$, and $R_{AC} = 10\ \Omega$. Calculate the value of R_A, R_B, and R_C.

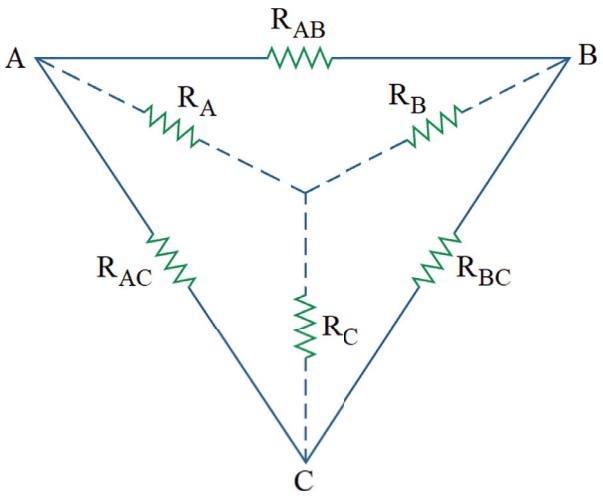


Fig. 1.15 The circuit of partially solved exercise 1.24

Solution

As we know, the following relations are valid when a delta-connection (Δ-connection or π-connection) is converted to a wye-connection (Y-connection, T-connection, or star-connection).

$$R_A = \frac{R_{AC}R_{AB}}{R_{AB} + R_{BC} + R_{AC}}$$

$$R_B = \frac{R_{AB}R_{BC}}{R_{AB} + R_{BC} + R_{AC}}$$

$$R_C = \frac{R_{AC}R_{BC}}{R_{AB} + R_{BC} + R_{AC}}$$

Therefore, for this problem, we can write as follows.

$$R_A = \frac{(\quad)(\quad)}{(\quad) + (\quad) + (\quad)}$$

$$\Rightarrow R_A = 5\ \Omega$$

$$R_B = \frac{(\quad)(\quad)}{(\quad) + (\quad) + (\quad)}$$

$$\Rightarrow R_B = 7.5\ \Omega$$

$$R_C = \frac{(\quad)(\quad)}{(\quad) + (\quad) + (\quad)}$$

$$\Rightarrow R_C = 3\ \Omega$$

Exercise

1.25. In the circuit of Fig. 1.16, calculate the equivalent resistance seen from the terminal.

Final Answer

$R_{eq} = 27\ \Omega$

Note: *Read the "educational support" part of the preface of the textbook.*

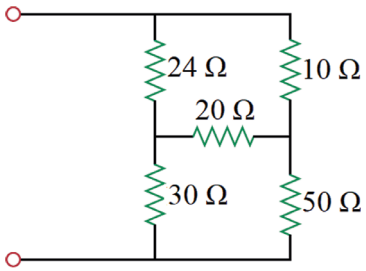


Fig. 1.16 The circuit of exercise 1.25

1.5 Heuristic Methods for Equivalent Resistance Calculation

Problem

1.26. In the circuit shown in Fig. 1.17, the resistor R is an Ohmic resistor and can take any value. In other words:

$$0 \leq R < \infty$$

Calculate the range of input resistance (R_{in}) seen from terminal a-b.

Difficulty level ○ Easy ○ Normal ● Hard

Calculation amount ○ Small ● Normal ○ Large



1) $0 < R_{in} < \infty$
2) $0.75 < R_{in} < \infty$
3) $0 < R_{in} < 0.83$
4) $0.78 < R_{in} < 0.83$

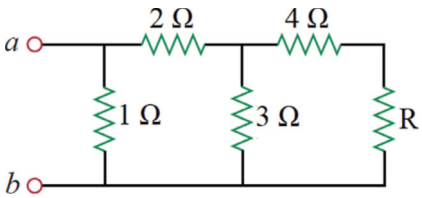


Fig. 1.17 The circuit of problem 1.26

Exercise

1.27. Calculate the range of resistance seen from the input terminal of the circuit illustrated in Fig. 1.18.

Final Answer

$0.66 < R_{in} < 1$

Note: *Read the "educational support" part of the preface of the textbook.*

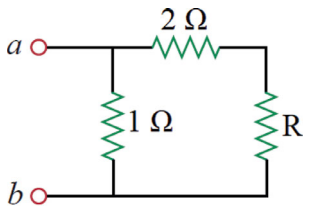


Fig. 1.18 The circuit of exercise 1.27

Problem

1.28. In the circuit illustrated in Fig. 1.19, all the resistors are 1 Ω. Calculate the equivalent resistance between the nodes "A" and "B".

Difficulty level ○ Easy ○ Normal ● Hard

Calculation amount ○ Small ● Normal ○ Large



1) $\frac{1}{4}$ Ω
2) $\frac{1}{3}$ Ω
3) $\frac{1}{2}$ Ω
4) $\frac{3}{4}$ Ω

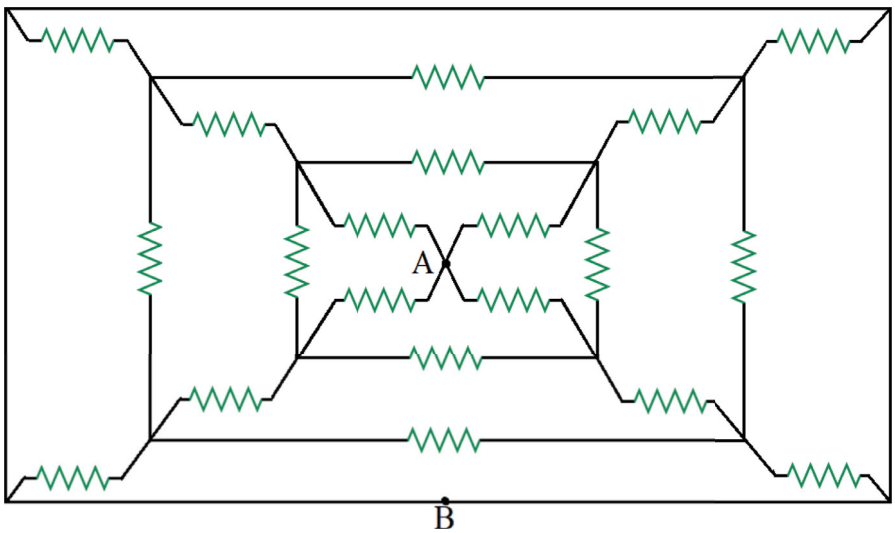


Fig. 1.19 The circuit of problem 1.28

Exercise

1.29. Calculate the equivalent resistance between the nodes "A" and "B" in the circuit of Fig. 1.20. Herein, all the resistors are 2 Ω.

Final Answer

$R_{AB} = 0$

Note: *Read the "educational support" part of the preface of the textbook.*

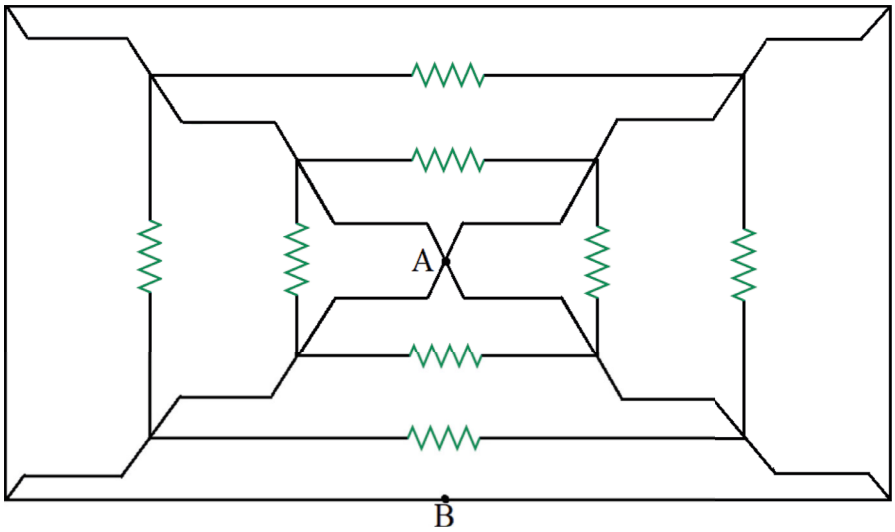


Fig. 1.20 The circuit of exercise 1.29

Problem

1.30. In the circuit of Fig. 1.21, suppose that the resistance of each resistor is R. Calculate the input resistance of the circuit.

Difficulty level ○ Easy ○ Normal ● Hard

Calculation amount ○ Small ● Normal ○ Large



1) R
2) 0.618 R
3) 0.5 R
4) 0.382 R