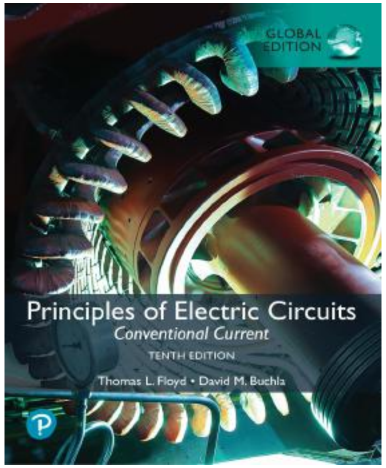
Principles of Electric Circuits: Conventional Current

Tenth Edition, Global Edition

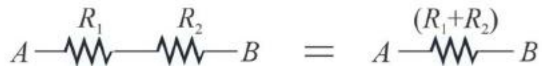


Chapter 7

Series-Parallel Circuits

Summary: Resistor equivalent combinations (1 of 5)

Most practical circuits have combinations of series and parallel components. You can frequently simplify analysis by combining series and parallel components. Recall that:



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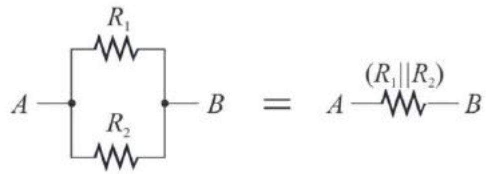
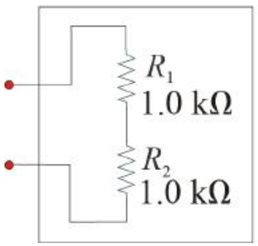


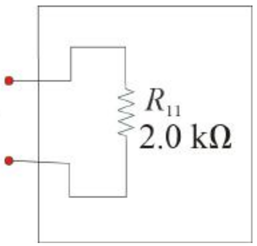
Let's look at some practical resistor combinations…. →

Summary: Resistor equivalent combinations (2 of 5)

For example:

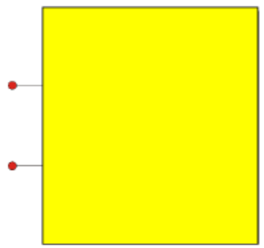


is equivalent to

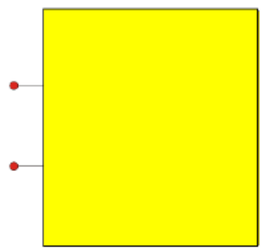


Summary: Resistor equivalent combinations (3 of 5)

For example:



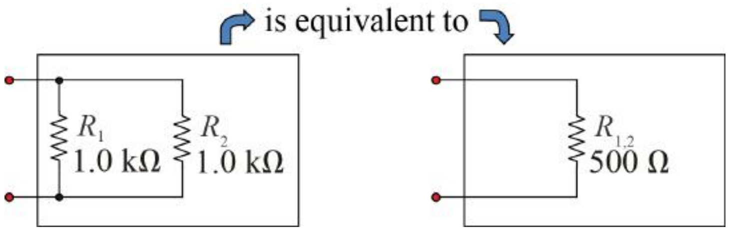
is equivalent to



There are no electrical measurements that can distinguish the boxes.

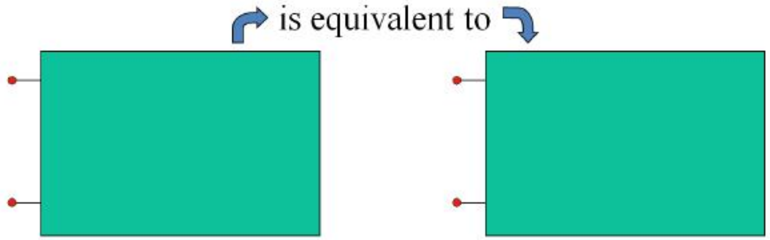
Summary: Resistor equivalent combinations (4 of 5)

Another example:



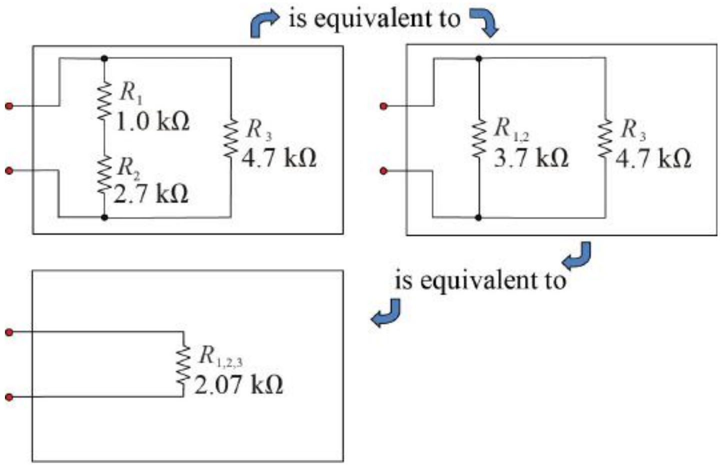
Summary: Resistor equivalent combinations (5 of 5)

Another example:

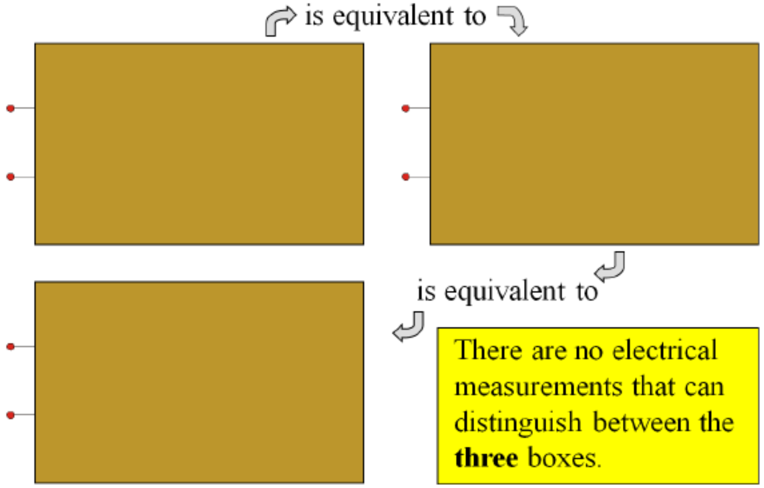


There are no electrical measurements that can distinguish the boxes.

Summary (1 of 3)



Summary (2 of 3)

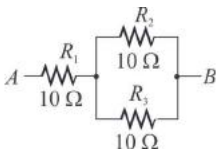


Summary: Resistor equivalent combinations (4 of 4)

Question:

Assume you needed a 15 Ω resistor but only have 10 Ω resistors. How would you get the required 15 Ω?

An equivalent 15 Ω can be made from 10 Ω resistors by connecting two 10 Ω resistors in parallel and connecting the parallel combination with one in series.

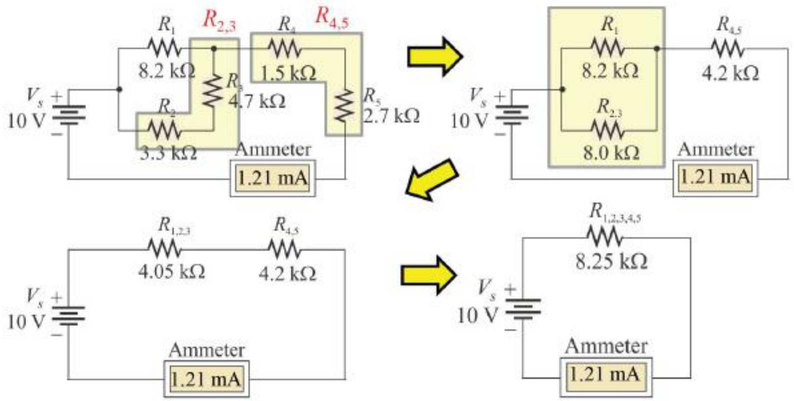


An important circuit analysis method is to form an **equivalent circuit** by combining components. This can simplify the analysis process. An equivalent circuit is one that has characteristics that are electrically the same as another circuit but is generally simpler.

Summary: Combination circuits (1 of 3)

Example:

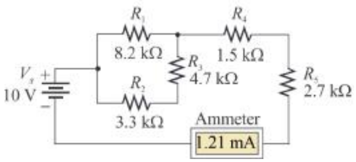
Assume you need to calculate the expected ammeter reading for the circuit. Follow the sequence:

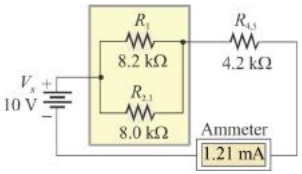


Summary: Combination circuits (2 of 3)

Question:

Can you use the equivalent circuits to find the remaining currents in the original circuit?





The total current goes through R_4 and R_5 and divides between R_1 and $R_{2,3}$. Applying the current divider rule:

$$I_1 = I_T\left(\frac{R_{2,3}}{R_1 + R_{2,3}}\right) = 1.21\text{ mA}\left(\frac{8.0\text{ k}\Omega}{8.2\text{ k}\Omega + 8.0\text{ k}\Omega}\right) = 0.60\text{ mA}$$

$$I_2 = I_T\left(\frac{R_1}{R_1 + R_{2,3}}\right) = 1.21\text{ mA}\left(\frac{8.2\text{ k}\Omega}{8.2\text{ k}\Omega + 8.0\text{ k}\Omega}\right) = 0.61\text{ mA}$$

Summarizing:

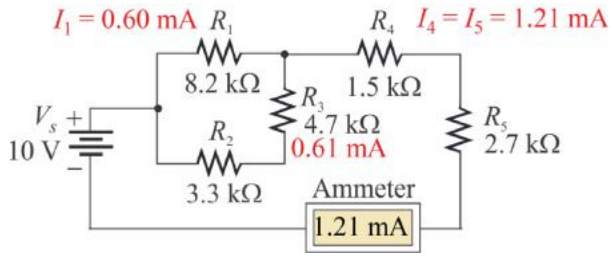
I_1 = 0.60 mA

$I_2 = I_3$ = 0.61 mA

$I_4 = I_5$ = 1.21 mA

Summary: Combination circuits (3 of 3)

It is a simple matter to find the voltage drops across the resistors now that the currents are known.



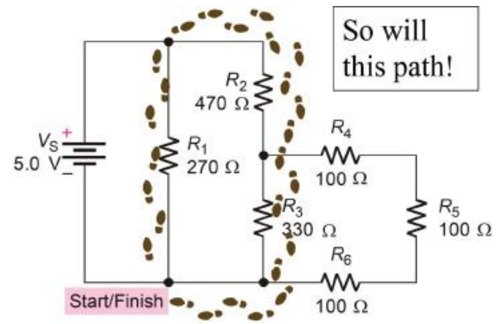
As a check on the currents, KVL can be applied to the outside loop. For this check, calculate V_1, V_4, and V_5.

$$V_1 = (0.60\text{ mA})(8.2\text{ k}\Omega) = 4.91\text{ V}$$
$$V_4 = (1.21\text{ mA})(1.5\text{ k}\Omega) = 1.82\text{ V}$$
$$V_5 = (1.21\text{ mA})(2.7\text{ k}\Omega) = 3.27\text{ V}$$
$$\text{Sum} = 10.0\text{ V}$$

Summary: Applying KVL and KCL

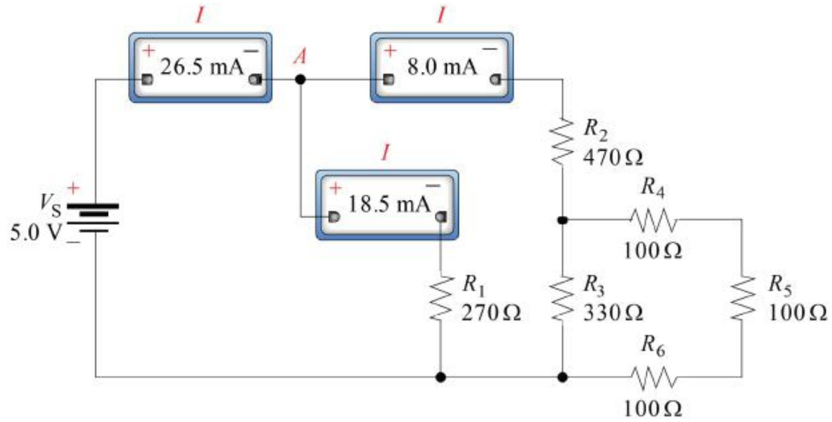
Kirchhoff's voltage law and **Kirchhoff's current law** can be applied to any circuit. This is a good accuracy check or to solve for an unknown.

For example, applying KVL, the path shown will have a sum of 0 V.

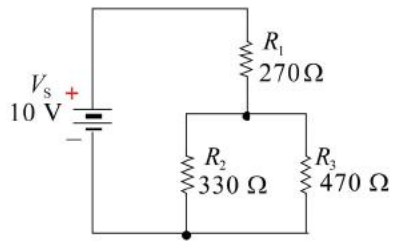


Summary (3 of 3)

Kirchhoff's current law can also be applied to the same circuit. What are the readings for node *A*?



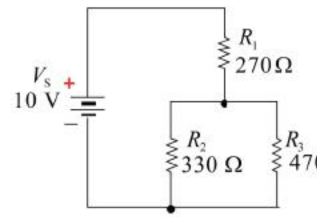
Summary: Combination circuits



Tabulating current, resistance, voltage and power is a useful way to summarize parameters. Solve for the unknown quantities in the circuit shown.

I_1= 21.6 mA	R_1= 270 Ω	V_1= 5.82 V	P_1= 126 mW
I_2= 12.7 mA	R_2= 330 Ω	V_2= 4.18 V	P_2= 53.1 mW
I_3= 8.9 mA	R_3= 470 Ω	V_3= 4.18 V	P_3= 37.2 mW
I_T= 21.6 mA	R_T= 464 Ω	V_S= 10 V	P_T= 216 mW

Summary: Kirchhoff's laws can be applied as a check on the answer

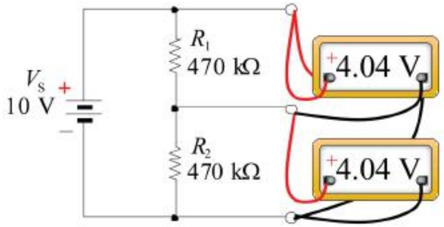


Notice that the current in R_1 is equal to the sum of the branch currents in R_2 and R_3.
The sum of the voltages around the outside loop is zero.

I_1= 21.6 mA	R_1= 270 Ω	V_1= 5.82 V	P_1= 125 mW
I_2= 12.7 mA	R_2= 330 Ω	V_2= 4.18 V	P_2= 52.9 mW
I_3= 8.9 mA	R_3= 470 Ω	V_3= 4.18 V	P_3= 37.2 mW
I_T= 21.6 mA	R_T= 464 Ω	V_S= 10 V	P_T= 216 mW

Summary: Loading effect of a voltmeter

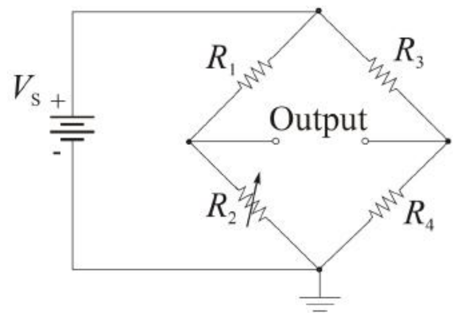
Assume V_S = 10 V, but the meter reads only 4.04 V when it is across either R_1 or R_2.



Can you explain what is happening?
All measurements affect the quantity being measured. A voltmeter has internal resistance, which can change the resistance of the circuit under test. In this case, a 1.0 MΩ internal resistance of the meter accounts for the readings.

Summary: Wheatstone bridge

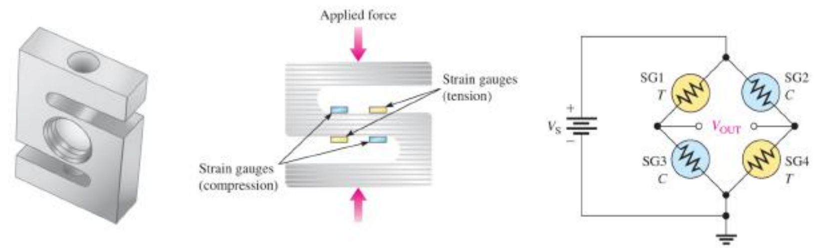
The Wheatstone bridge consists of four resistive arms forming two voltage dividers and a dc voltage source. The output is taken between the dividers. Frequently, one of the bridge resistors is adjustable.



When the bridge is balanced, the output voltage is zero, and the products of resistances in the opposite diagonal arms are equal.

Summary: Application of the Wheatstone bridge

Wheatstone bridges are used in load cells, which are widely used in scales. The bridge arms are constructed from four strain gauges - two are in tension and two in compression.



(a) A typical S-type load cell (b) A load cell with four active strain gauges (two compression, two tension) (c) Wheatstone bridge

Key Terms (1 of 2)

Balanced bridge A bridge circuit that is in the balanced state as indicated by 0 V across the output.

Bleeder current The current left after the load current is subtracted from the total current into the circuit.

Load An element (resistor or other component) connected across the output terminals of a circuit that draws current from the circuit.

Key Terms (2 of 2)

Unbalanced bridge A bridge circuit that is in the unbalanced state as indicated by a voltage across the output that is proportional to the amount of deviation from the balanced state.

Wheatstone bridge A 4-legged type of bridge circuit with which an unknown resistance can be accurately measured using the balanced state. Deviations in resistance can be measured using the unbalanced state.

Quiz (1 of 11)

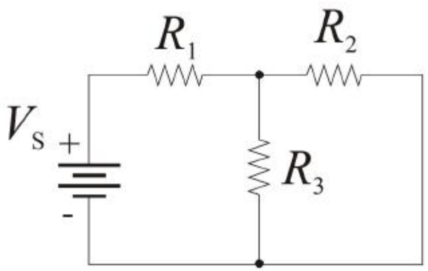
1. Two circuits that are equivalent have the same
   a. number of components
   b. response to an electrical stimulus
   c. internal power dissipation
   d. all of the above

Quiz (2 of 11)

2. If a series equivalent circuit is drawn for a complex circuit, the equivalent circuit can be analyzed with
   a. the voltage divider theorem
   b. Kirchhoff's voltage law
   c. both of the above
   d. none of the above

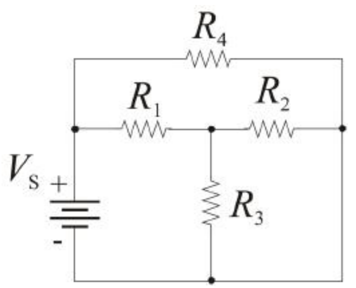
Quiz (3 of 11)

3. For the circuit shown,
   a. R_1 is in series with R_2
   b. R_1 is in parallel with R_2
   c. R_2 is in series with R_3
   d. R_2 is in parallel with R_3



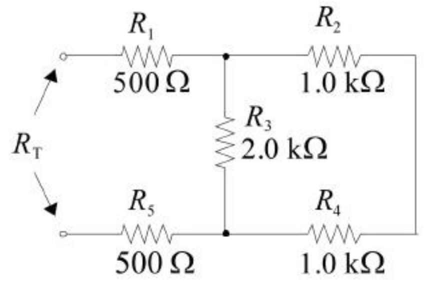
Quiz (4 of 11)

4. For the circuit shown,
   a. R_1 is in series with R_2
   b. R_4 is in parallel with R_1
   c. R_2 is in parallel with R_3
   d. none of the above



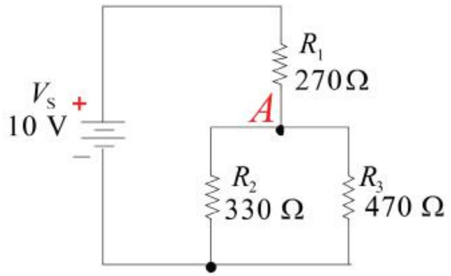
Quiz (5 of 11)

5. The total resistance, R_T, of the group of resistors is
   a. 1.0 kΩ
   b. 2.0 kΩ
   c. 3.0 kΩ
   d. 4.0 kΩ



Quiz (6 of 11)

6. For the circuit shown, Kirchhoff's voltage law
   a. applies only to the outside loop
   b. applies only to the *A* junction.
   c. can be applied to any closed path.
   d. does not apply.

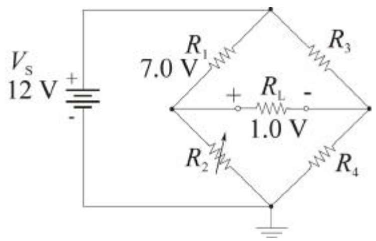


Quiz (7 of 11)

7. The effect of changing a measured quantity due to connecting an instrument to a circuit is called
   a. loading
   b. clipping
   c. distortion
   d. loss of precision

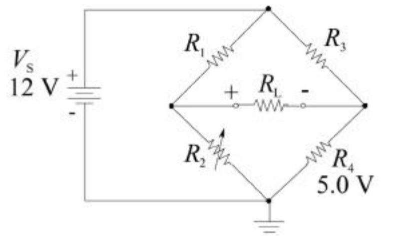
Quiz (8 of 11)

8. An unbalanced Wheatstone bridge has the voltages shown. The voltage across R_4 is
   - a. 4.0 V
   - b. 5.0 V
   - c. 6.0 V
   - d. 7.0 V



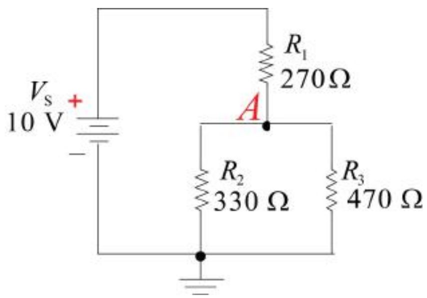
Quiz (9 of 11)

9. Assume R_2 is adjusted until the Wheatstone bridge is balanced. At this point, the voltage across R_4 is measured and found to be 5.0 V. The voltage across R_1 will be
   - a. 4.0 V
   - b. 5.0 V
   - c. 6.0 V
   - d. 7.0 V



Quiz (10 of 11)

10. For the circuit shown, if R_3 opens, the voltage at point A will
    - a. decrease
    - b. stay the same.
    - c. increase.



Quiz (11 of 11)

Answers:

1. b
2. c
3. d
4. c
5. b
6. c
7. a
8. a
9. d
10. c

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