CHAPTER 3: SIMPLE RESISTIVE CIRCLES

Summary

- **Series resistors** can be combined to obtain a single equivalent resistance according to the equation

$$R_{\text{eq}} = \sum_{i=1}^{k} R_i = R_1 + R_2 + \cdots + R_k.$$

(See page 80.)

- **Parallel resistors** can be combined to obtain a single equivalent resistance according to the equation

$$\frac{1}{R_{\text{eq}}} = \sum_{i=1}^{k} \frac{1}{R_i} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_k}.$$

When just two resistors are in parallel, the equation for equivalent resistance can be simplified to give

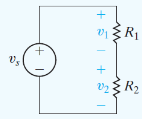
$$R_{\text{eq}} = \frac{R_1 R_2}{R_1 + R_2}.$$

(See pages 81–82.)

- When voltage is divided between series resistors, as shown in the figure, the voltage across each resistor can be found according to the equations

$$v_1 = \frac{R_1}{R_1 + R_2} v_s,$$

$$v_2 = \frac{R_2}{R_1 + R_2} v_s.$$

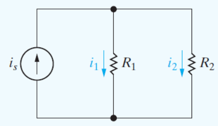


(See page 83.)

- When current is divided between parallel resistors, as shown in the figure, the current through each resistor can be found according to the equations

$$i_1 = \frac{R_2}{R_1 + R_2} i_s,$$

$$i_2 = \frac{R_1}{R_1 + R_2} i_s.$$



(See page 85.)

- **Voltage division** is a circuit analysis tool that is used to find the voltage drop across a single resistance from a collection of series-connected resistances when the voltage drop across the collection is known:

$$v_j = \frac{R_j}{R_{\text{eq}}} v,$$

where v_j is the voltage drop across the resistance R_j and v is the voltage drop across the series-connected resistances whose equivalent resistance is R_{eq}. (See page 87.)

- **Current division** is a circuit analysis tool that is used to find the current through a single resistance from a collection of parallel-connected resistances when the current into the collection is known:

$$I_j = \frac{R_{\text{eq}}}{R_j} i,$$

where i_j is the current through the resistance R_j and i is the current into the parallel-connected resistances whose equivalent resistance is R_{eq}. (See page 87.)

- A **voltmeter** measures voltage and must be placed in parallel with the voltage being measured. An ideal voltmeter has infinite internal resistance and thus does not alter the voltage being measured. (See page 88.)

- An **ammeter** measures current and must be placed in series with the current being measured. An ideal ammeter has zero internal resistance and thus does not alter the current being measured. (See page 88.)

- **Digital meters** and **analog meters** have internal resistance, which influences the value of the circuit variable being measured. Meters based on the d'Arsonval meter movement deliberately include internal resistance as a way to limit the current in the movement's coil. (See page 89.)

- The **Wheatstone bridge** circuit is used to make precise measurements of a resistor's value using four resistors, a dc voltage source, and a galvanometer. A Wheatstone bridge is balanced when the resistors obey Eq. 3.33, resulting in a galvanometer reading of 0 A. (See page 91.)

- A circuit with three resistors connected in a Δ configuration (or a π configuration) can be transformed into an equivalent circuit in which the three resistors are Y connected (or T connected). The Δ-to-Y transformation is given by Eqs. 3.44–3.46; the Y-to-Δ transformation is given by Eqs. 3.47–3.49. (See page 94.)

direct current (DC) sources: constant sources

3.1 Resistors in Series

series-connected circuit elements carry the same current

Combining resistors in series:

$$R_{eq} = \sum_{i=1}^{k} R_i = R_1 + R_2 + \ldots + R_k$$

3.2 Resistors in Parallel

parallel-connected circuit elements:

- same voltage across terminals
- parallel when 2 elements connect at single node pair

Combining resistors in parallel*:

$$\frac{1}{R_{eq}} = \sum_{i=1}^{k} \frac{1}{R_i} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots + \frac{1}{R_k}$$

$$G_{eq} = \sum_{i=1}^{k} G_i = G_1 + G_2 + \ldots + G_k$$

*total is always smaller than each resistance

3.3 The Voltage-Divider & Current-Divider Circuits

voltage-divider circuit: more than one voltage level from a single supply

$$v_i = v_s \frac{R_i}{\sum_{i=1}^{k} R_i}$$

*voltage to source ratio is equal to resistance to total resistance ratio

load: consists of one or more circuit elements that draw power from circuit

current-divider circuit: 2 resistors connected in parallel across current source

$$i_i = i_s \frac{R_i}{\sum_{i=1}^{k} R_i}$$

3.4 Voltage Division & Circuit Division

voltage division equation:

$$v_j = iR_j = \frac{R_j}{R_{eq}} v$$

current division equation:

$$i_j = \frac{v}{R_j} = \frac{R_{eq}}{R_j} i$$

3.5 Measuring Voltage & Current

ammeter: instrument designed to measure current (placed in series with circuit element to be measured)

voltmeter: instrument designed to measure voltage (placed parallel with element to be measured)

digital meters: measures continuous voltage/ current signal at discrete points in time (sampling times)

analog meters: based on d'Arsonval* meter movement (readout mechanism)

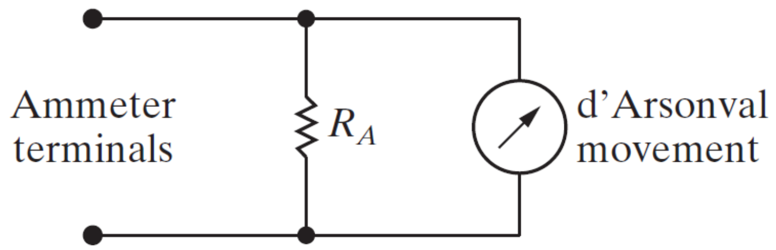


Figure 3.24 ▲ A dc ammeter circuit.

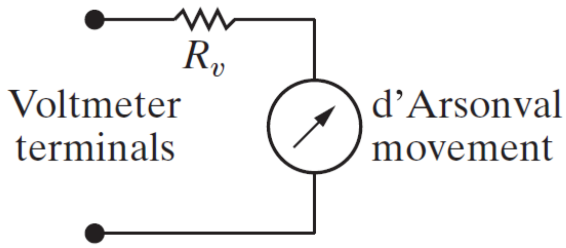


Figure 3.25 ▲ A dc voltmeter circuit.

- analog ammeter: in parallel with resistor; limits amount of current in movement's coil
- analog voltmeter: in series with resistor; limits amount of voltage drop across coil

*non-ideal; rule of 1/10

3.6 Measuring Resistance -- The Wheatstone Bridge

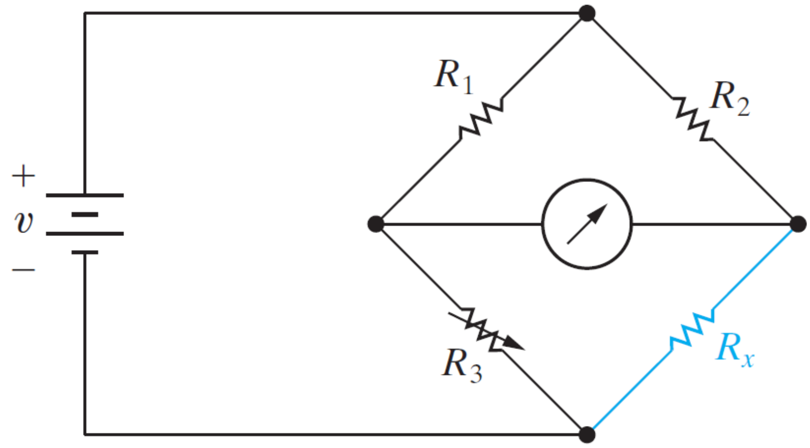


Figure 3.26 ▲ The Wheatstone bridge circuit.

- used to precisely measure resistances of medium values (range 1 Ω to 1 MΩ)

galvanometer: d'Arsonval movement in microamp range

Adjust R_3 until no current in galvanometer:

$$R_x = \frac{R_2}{R_1} R_3$$

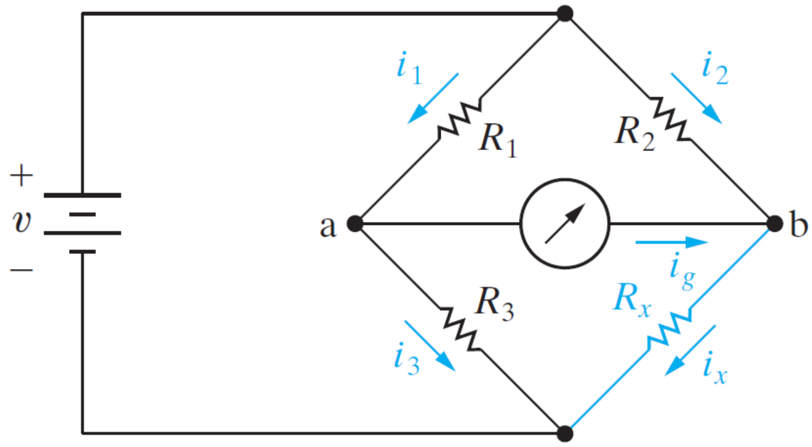


Figure 3.27 ▲ A balanced Wheatstone bridge ($i_g = 0$).

*when i_g is zero, bridge is balanced: $i_1 = i_3$, $i_2 = i_x$.

3.7 Delta-to-Wye (Pi-to-Tee) Equivalent Circuits

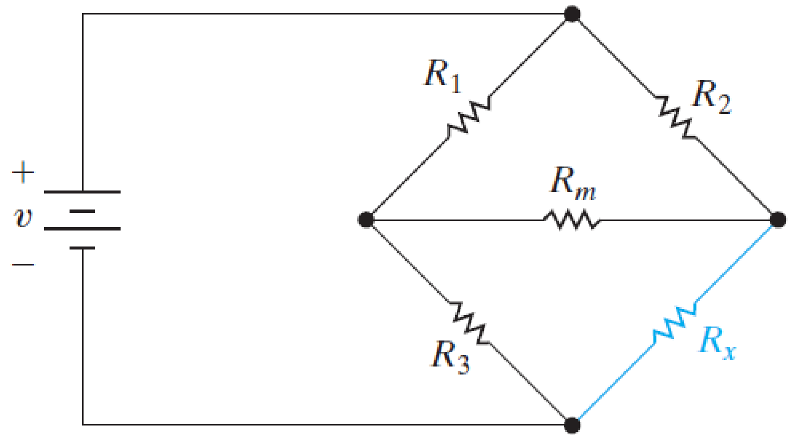


Figure 3.28 ▲ A resistive network generated by a Wheatstone bridge circuit.

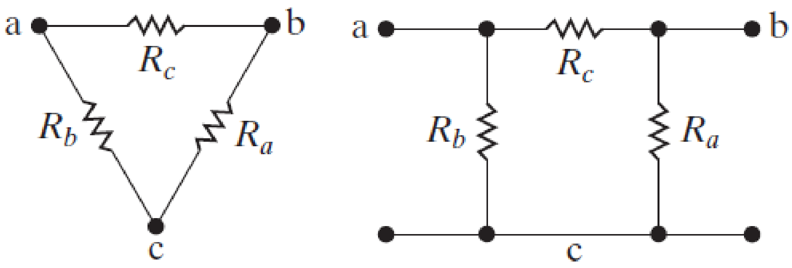


Figure 3.29 ▲ A Δ configuration viewed as a π configuration.

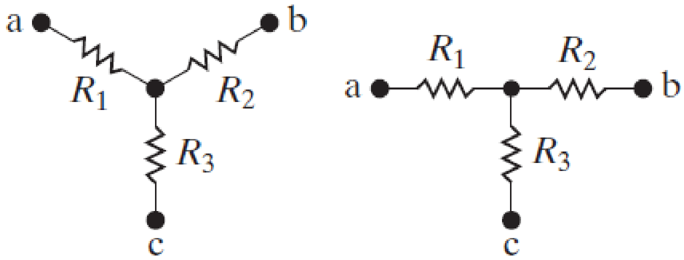


Figure 3.30 ▲ A Y structure viewed as a T structure.

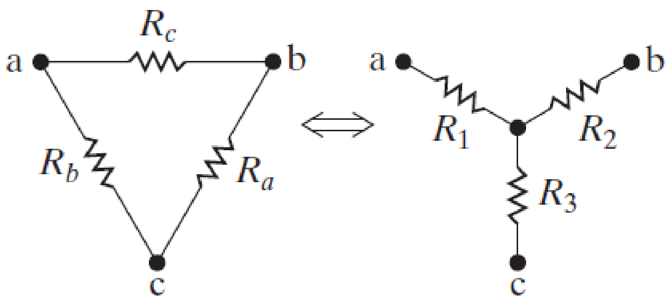


Figure 3.31 ▲ The Δ-to-Y transformation.