Introduction to Electrical circuits

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Grading System

1	Attendance	5%
2	Technical reports/ Assignments	10%
3	Midterm exam	20%
4	Quizzes	5%
5	Final Exam	60%
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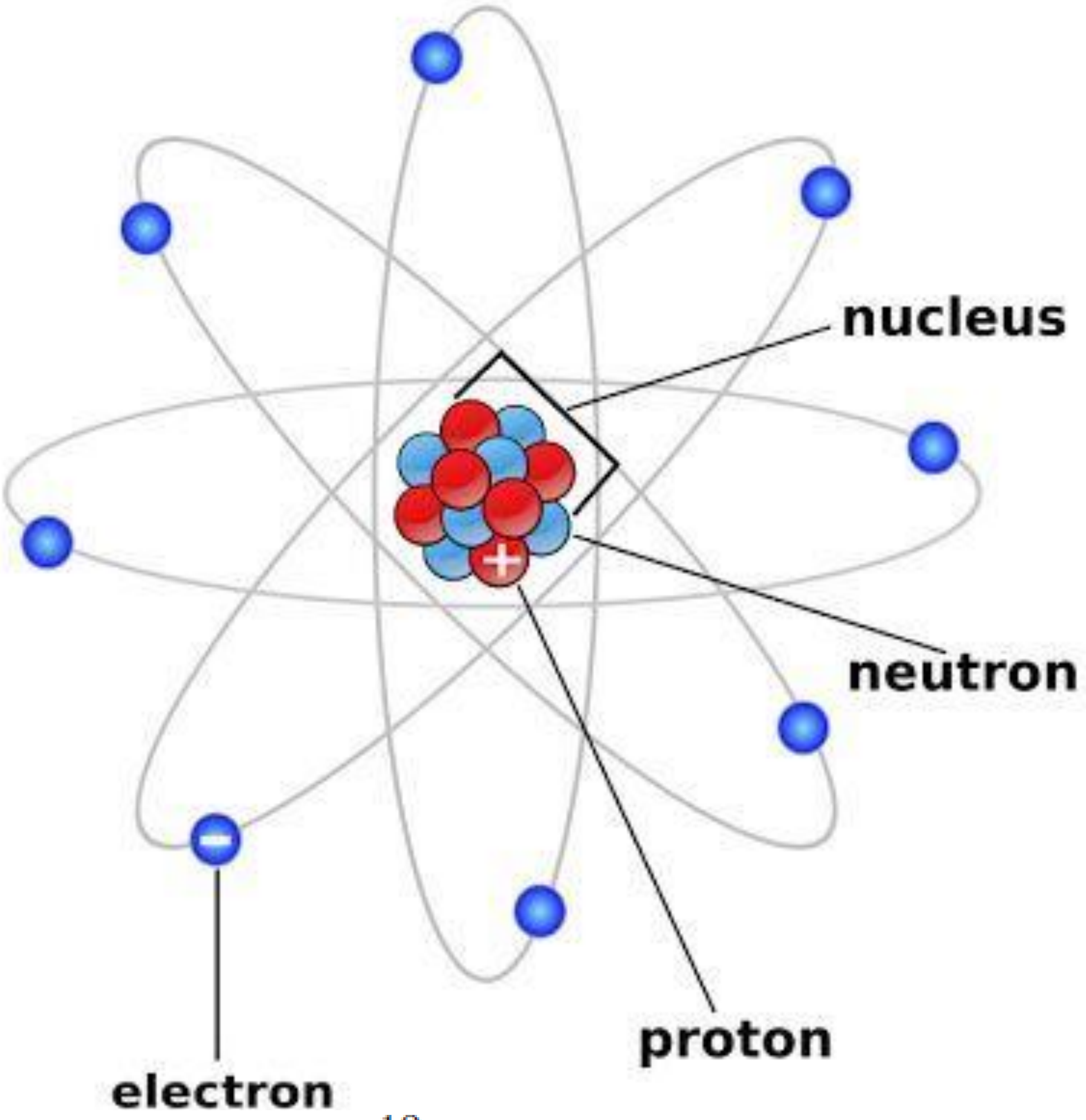
Ref: Fundamentals of Electric Circuits, Charles K. Alexander, 5th edition

Introduction

Charge is an electrical property of the atomic particles of which matter consists, measured in coulombs (C).



$e = -1.602 \times 10^{-19}$ C.

The SI prefixes.

Multiplier	Prefix	Symbol
10^{18}	exa	E
10^{15}	peta	P
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hecto	h
10	deka	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a

Introduction

The **law of conservation** of charge states that charge can neither be created nor destroyed, only transferred, Thus the algebraic sum of the electric charges in a system does not change.

Electric current

Electric current is the time rate of change of charge, measured in amperes (A).

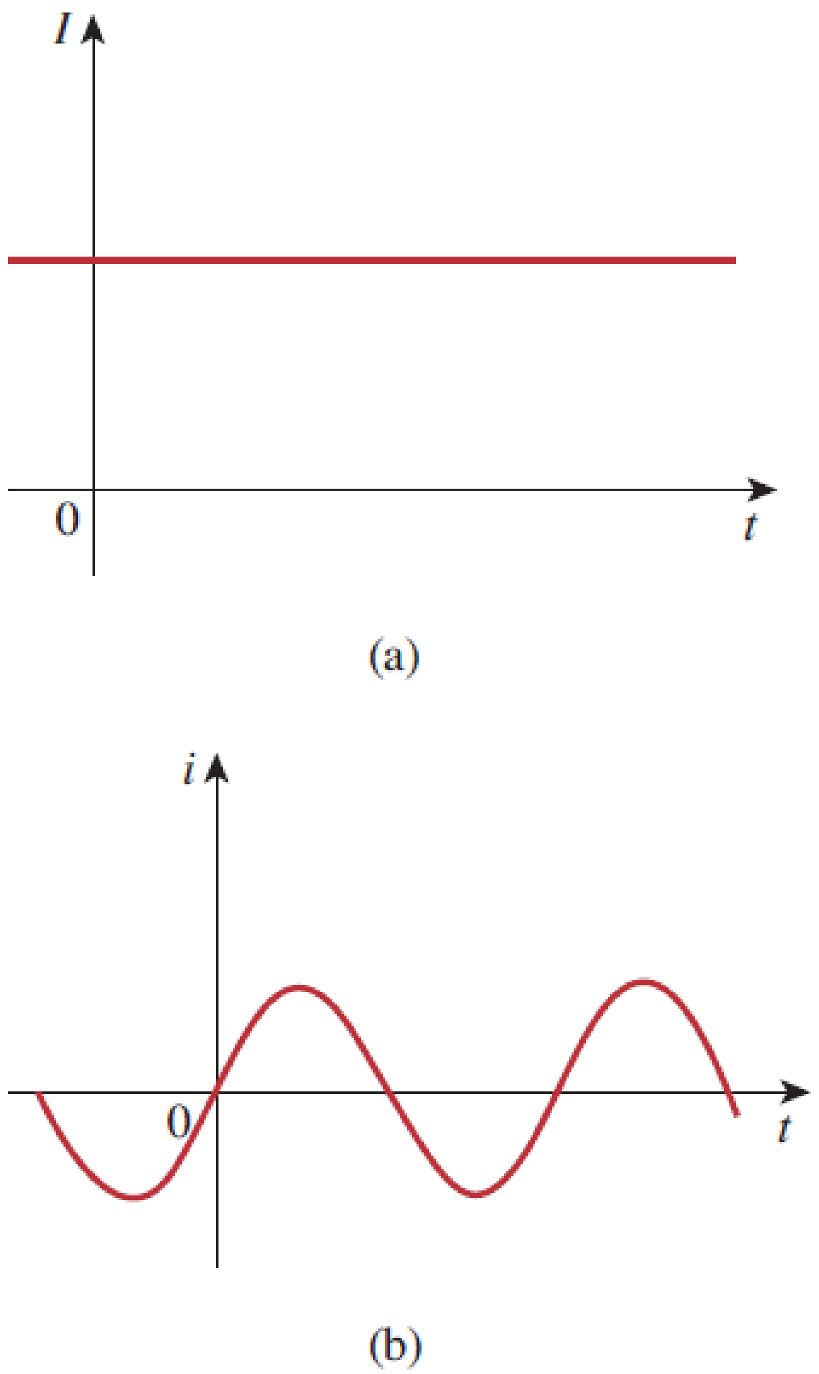
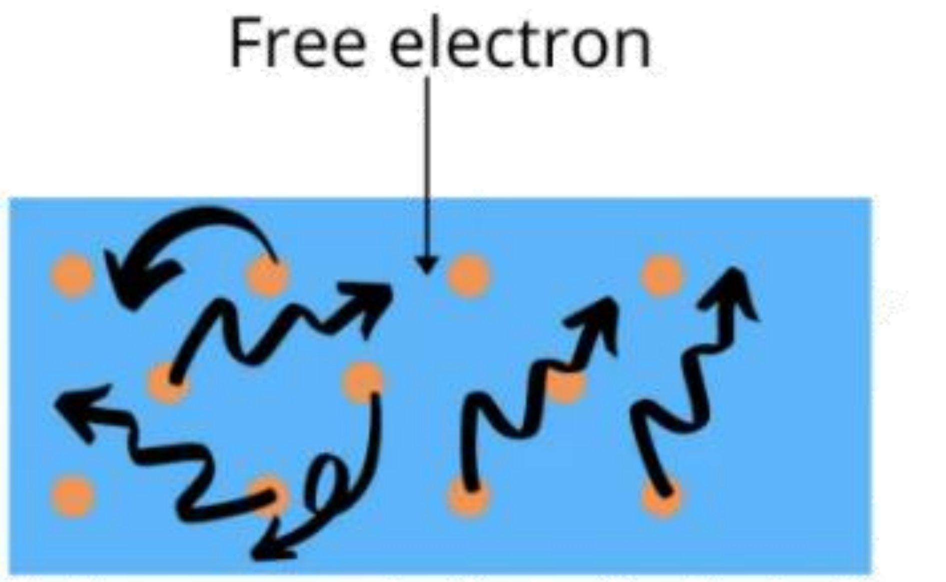
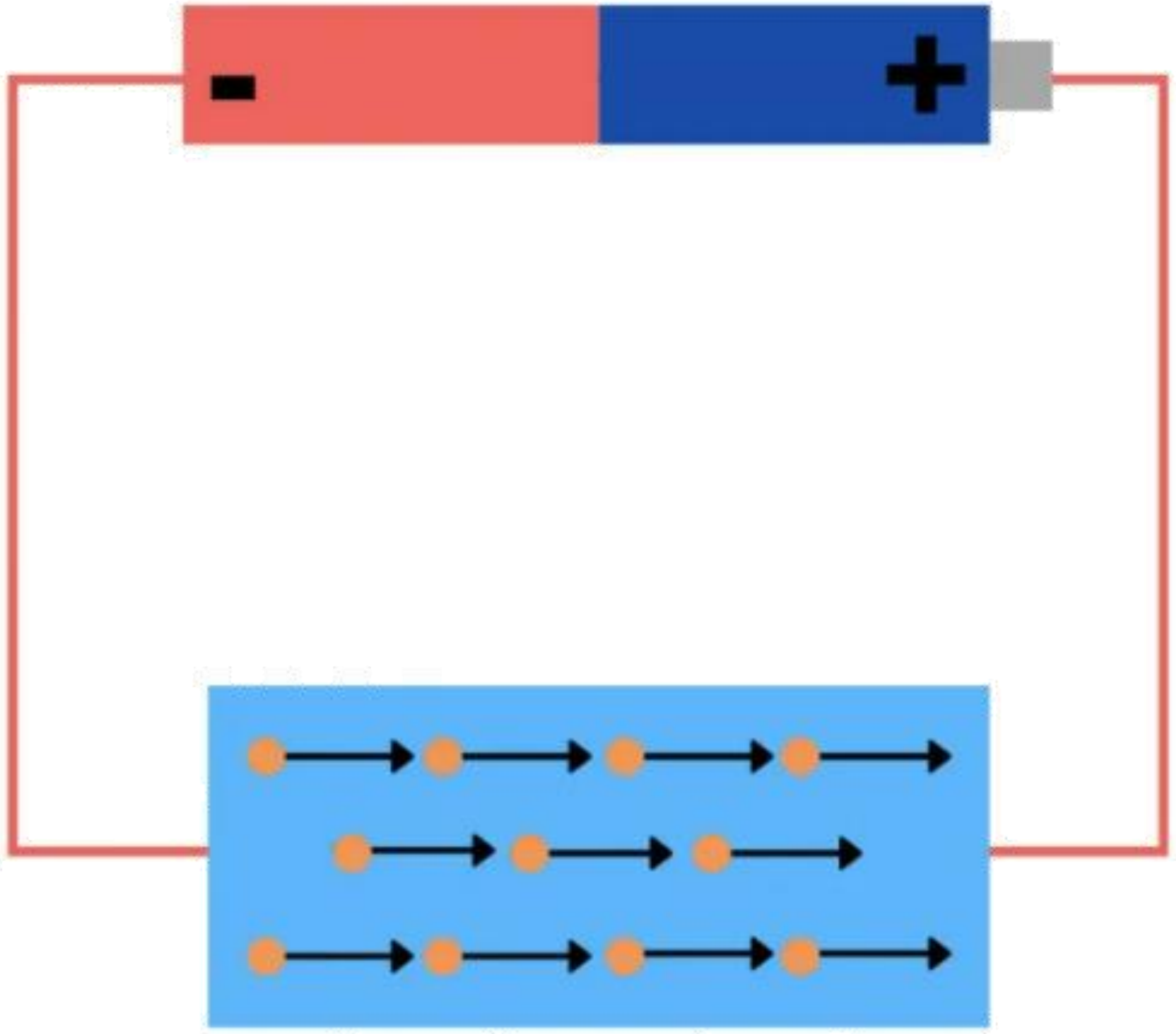


Figure 1.4
Two common types of current: (a) direct current (dc), (b) alternating current (ac).

$$i \triangleq \frac{dq}{dt}$$



Free electron movement when not having the current.



Electron movement when having the current.

Electric current

Voltage (or potential difference) is the energy required to move a unit charge through an element, measured in volts (V).

Power is the time rate of expending or absorbing energy, measured in watts (W).

$$p = vi$$

Resistance

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

The resistance R of an element denotes its ability to resist the flow of electric current; it is measured in ohms (Ω).

Material	Resistivity (Ω·m)	Usage
Silver	1.64×10^{-8}	Conductor
Copper	1.72×10^{-8}	Conductor
Aluminum	2.8×10^{-8}	Conductor
Gold	2.45×10^{-8}	Conductor
Carbon	4×10^{-5}	Semiconductor
Germanium	47×10^{-2}	Semiconductor
Silicon	6.4×10^{2}	Semiconductor
Paper	10^{10}	Insulator
Mica	5×10^{11}	Insulator

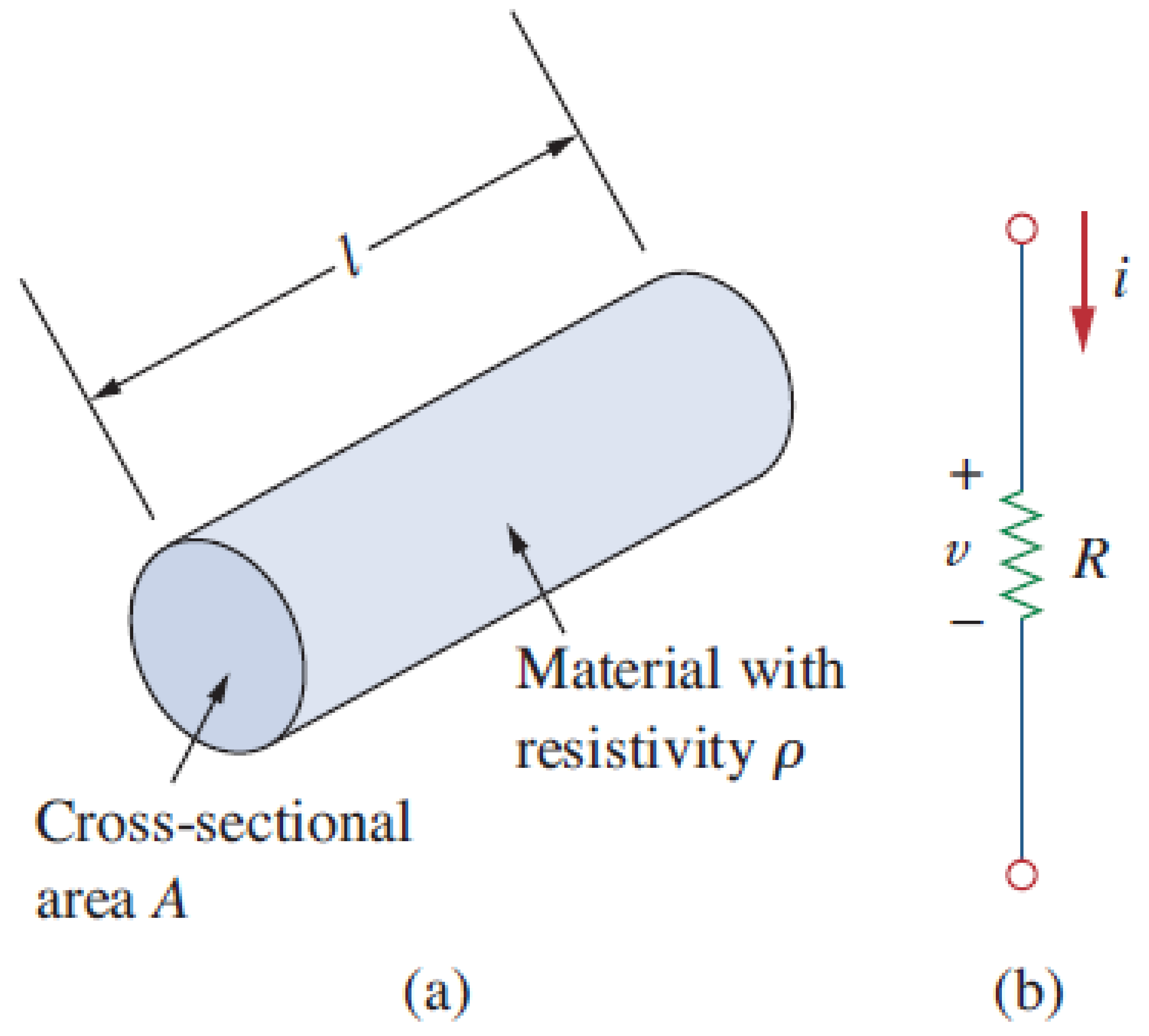
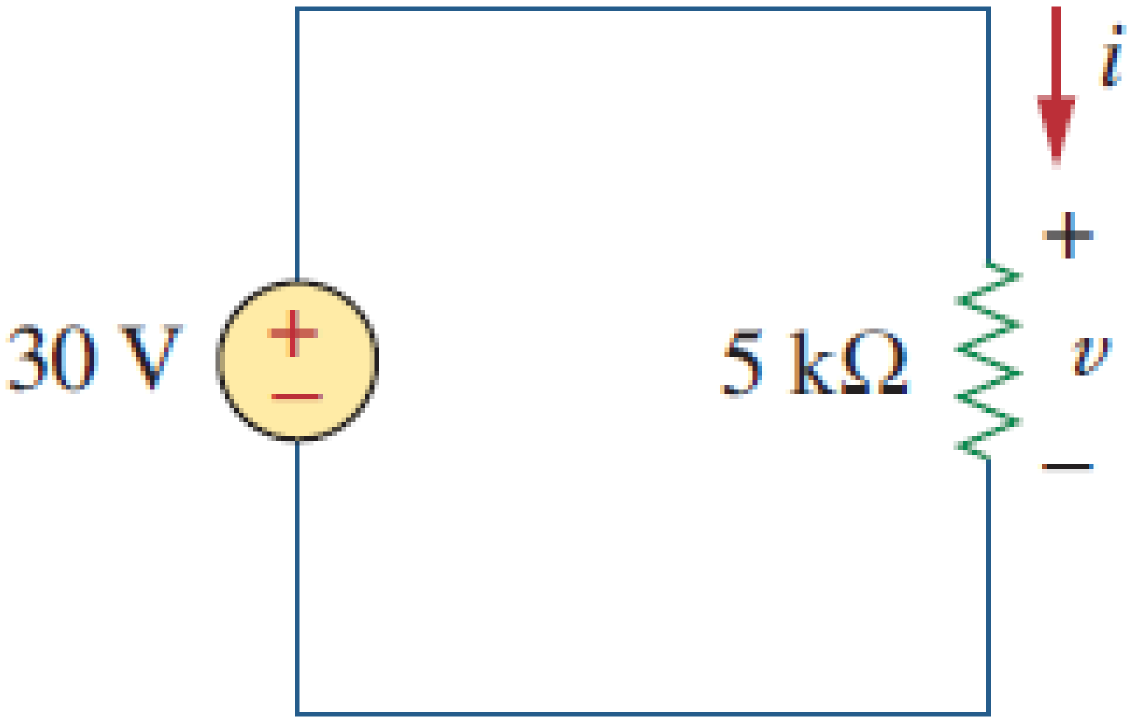


Figure 2.1
(a) Resistor, (b) Circuit symbol for resistance.

Ohm's law

Ohm's law states that the voltage v across a resistor is directly proportional to the current i flowing through the resistor.

$$v = iR$$



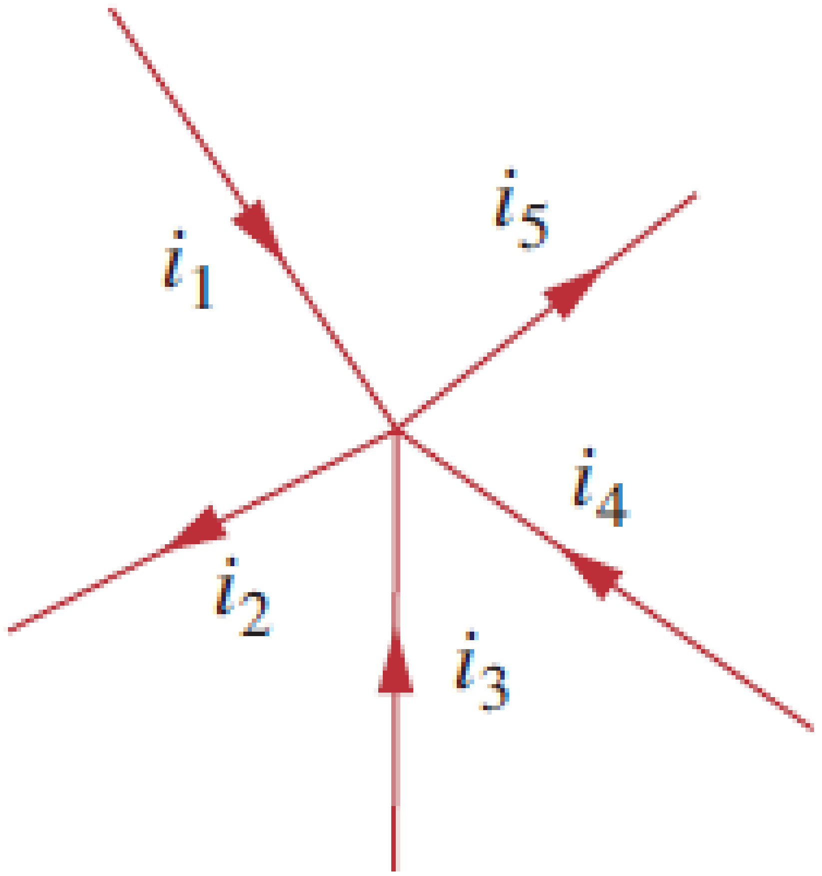
$$i = \frac{v}{R} = \frac{30}{5 \times 10^3} = 6 \text{ mA}$$

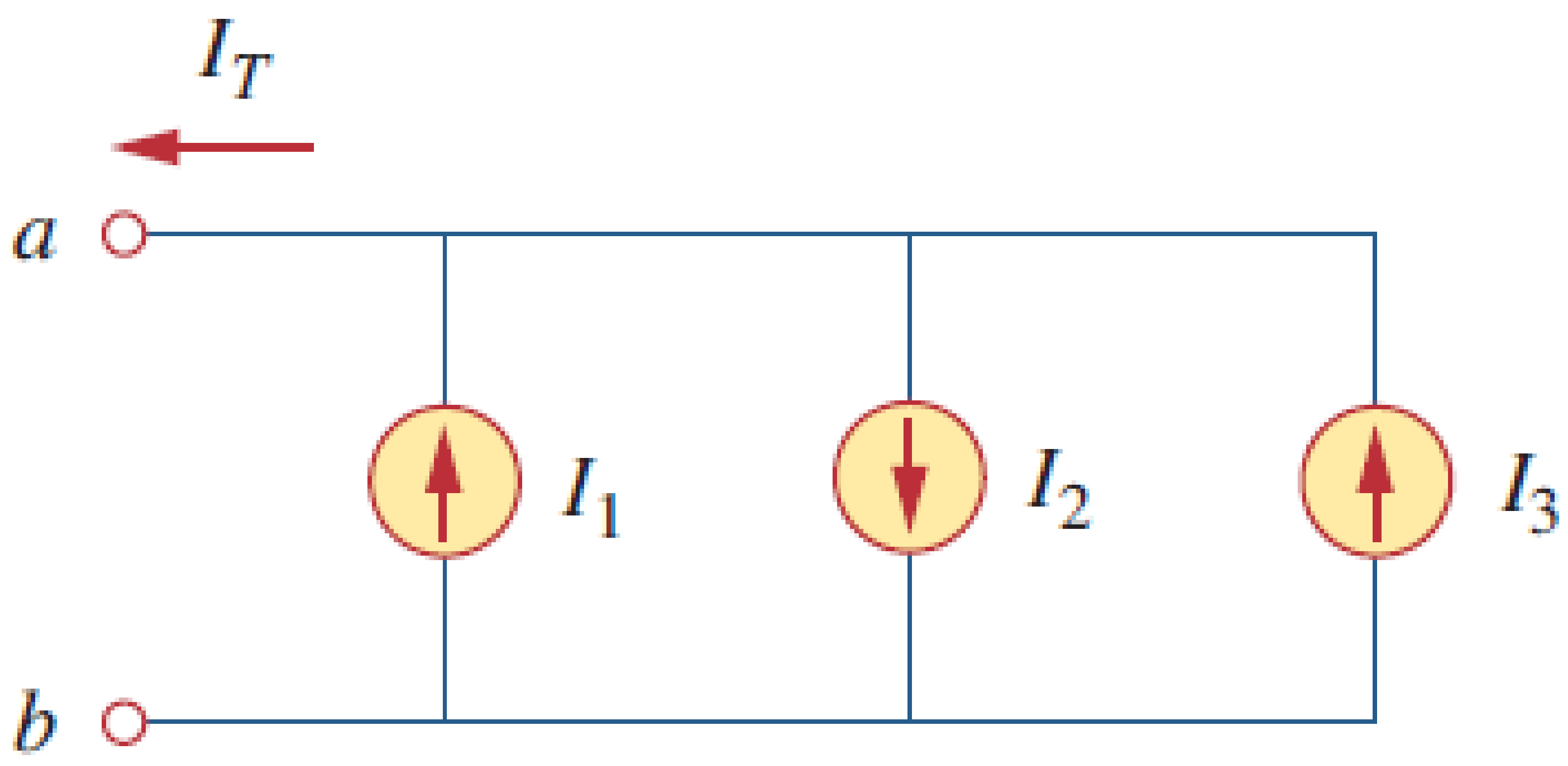
$$p = vi = 30(6 \times 10^{-3}) = 180 \text{ mW}$$

Kirchhoff's law

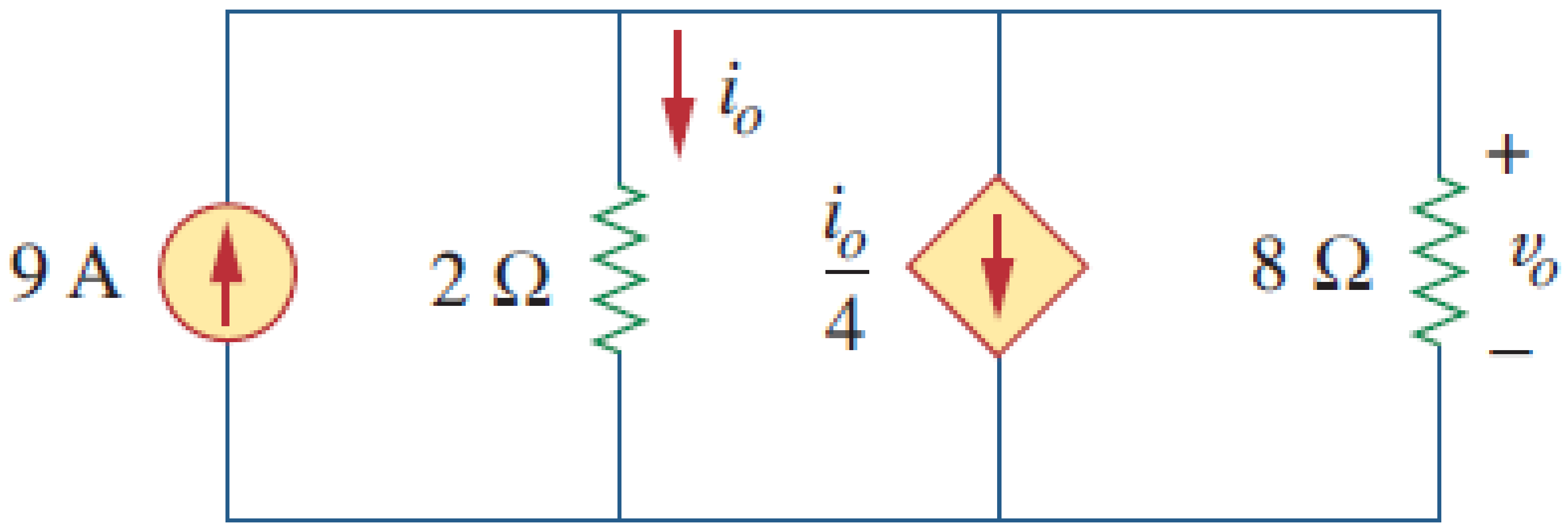
Kirchhoff's current law (KCL) states that the algebraic sum of currents entering a node (or a closed boundary) is zero

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

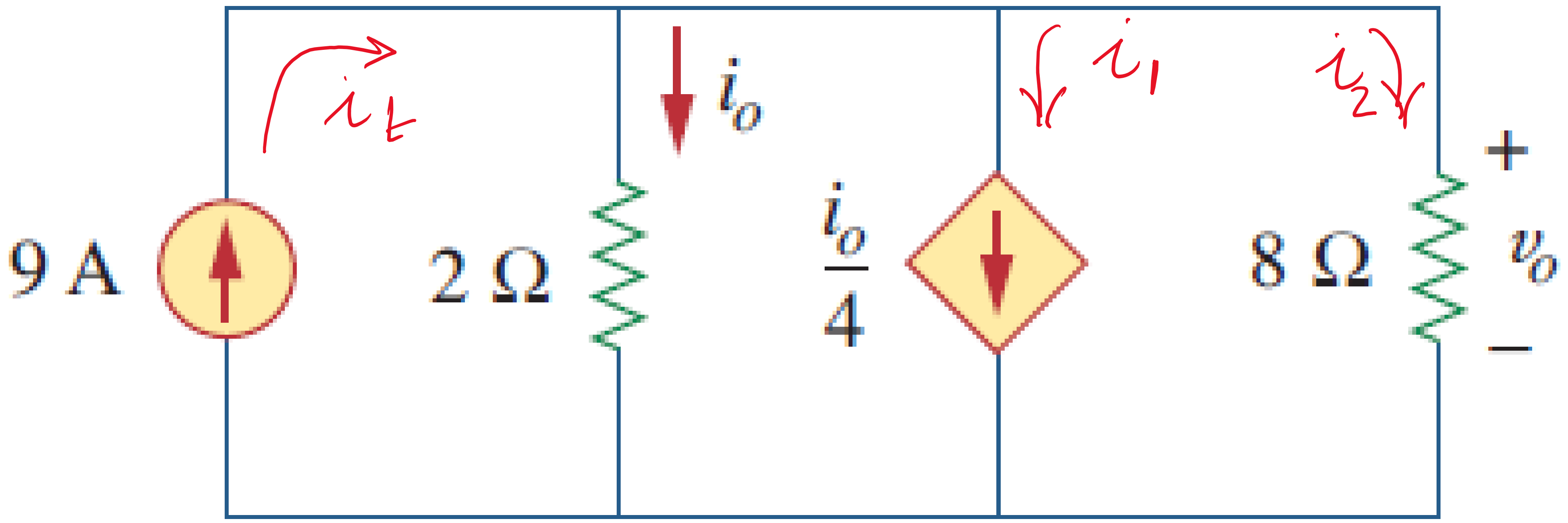




Exercise 1



Exercise 1



Soln.

$$\sum i = 0$$

$$i_t = i_o + i_1 + i_2$$

$$9 = \frac{v_o}{2} + \frac{i_o}{4} + \frac{v_o}{8}$$

$$\therefore i_o = \frac{v_o}{2}$$

$$9 = \frac{v_o}{2} + \frac{v_o}{8} + \frac{v_o}{8} \Rightarrow v_o = 12\,V$$

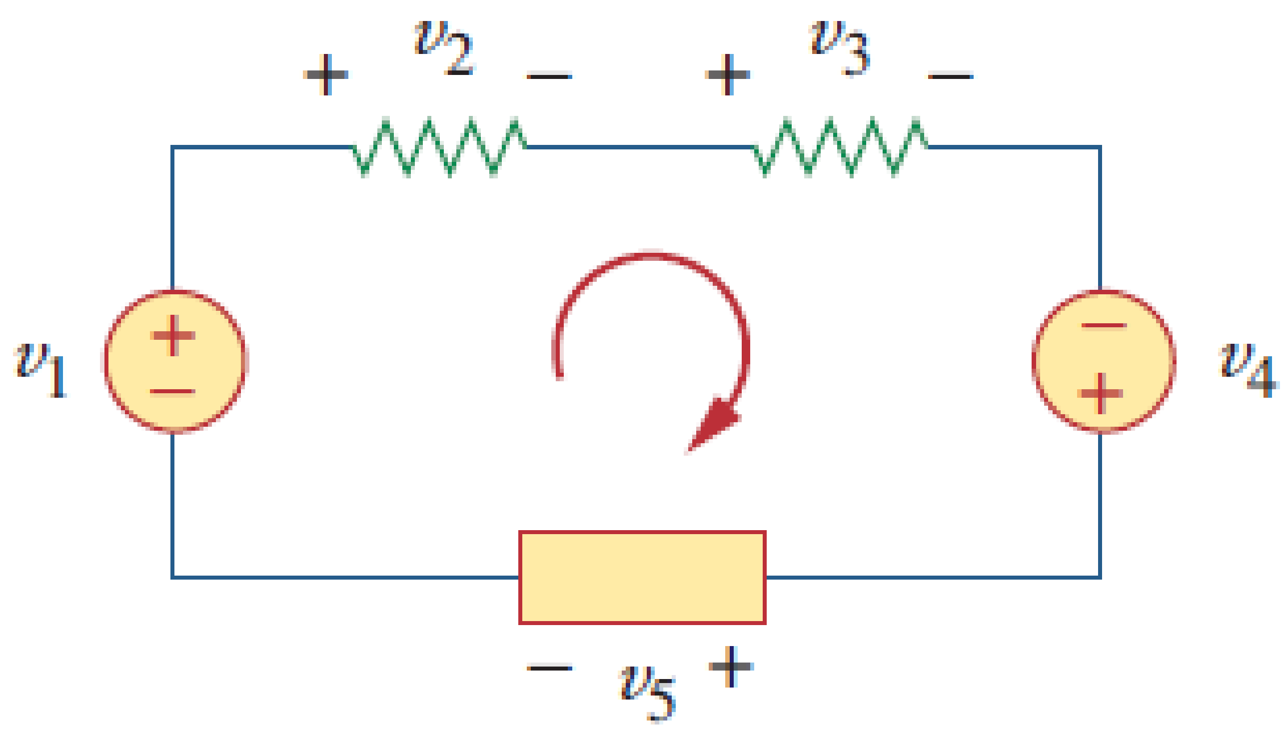
$$\therefore i_o = \frac{v_o}{2}$$

$$i_o = 6A$$

Kirchhoff's law

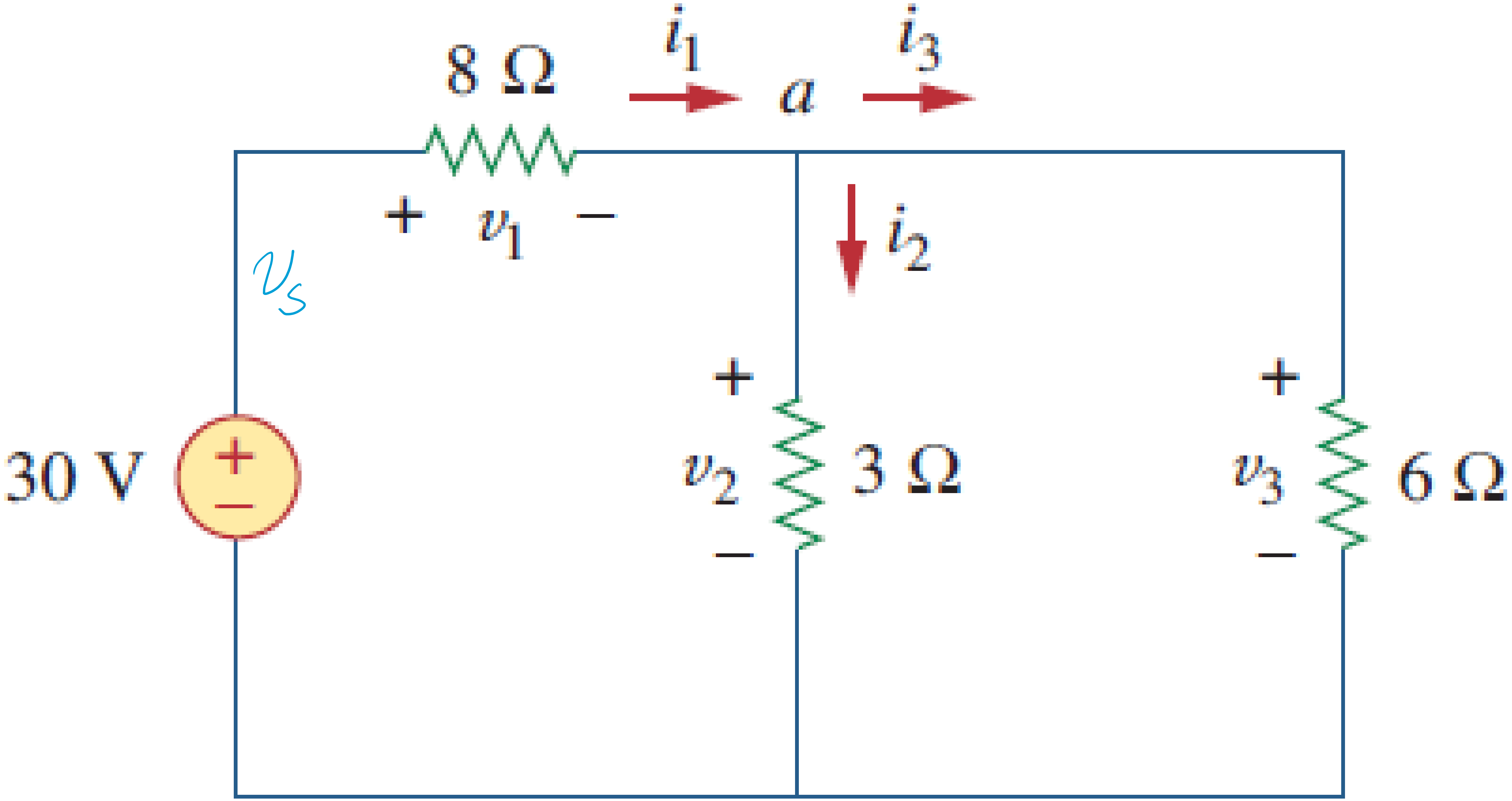
Kirchhoff's voltage law (KVL) states that the algebraic sum of all voltages around a closed path (or loop) is zero.

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

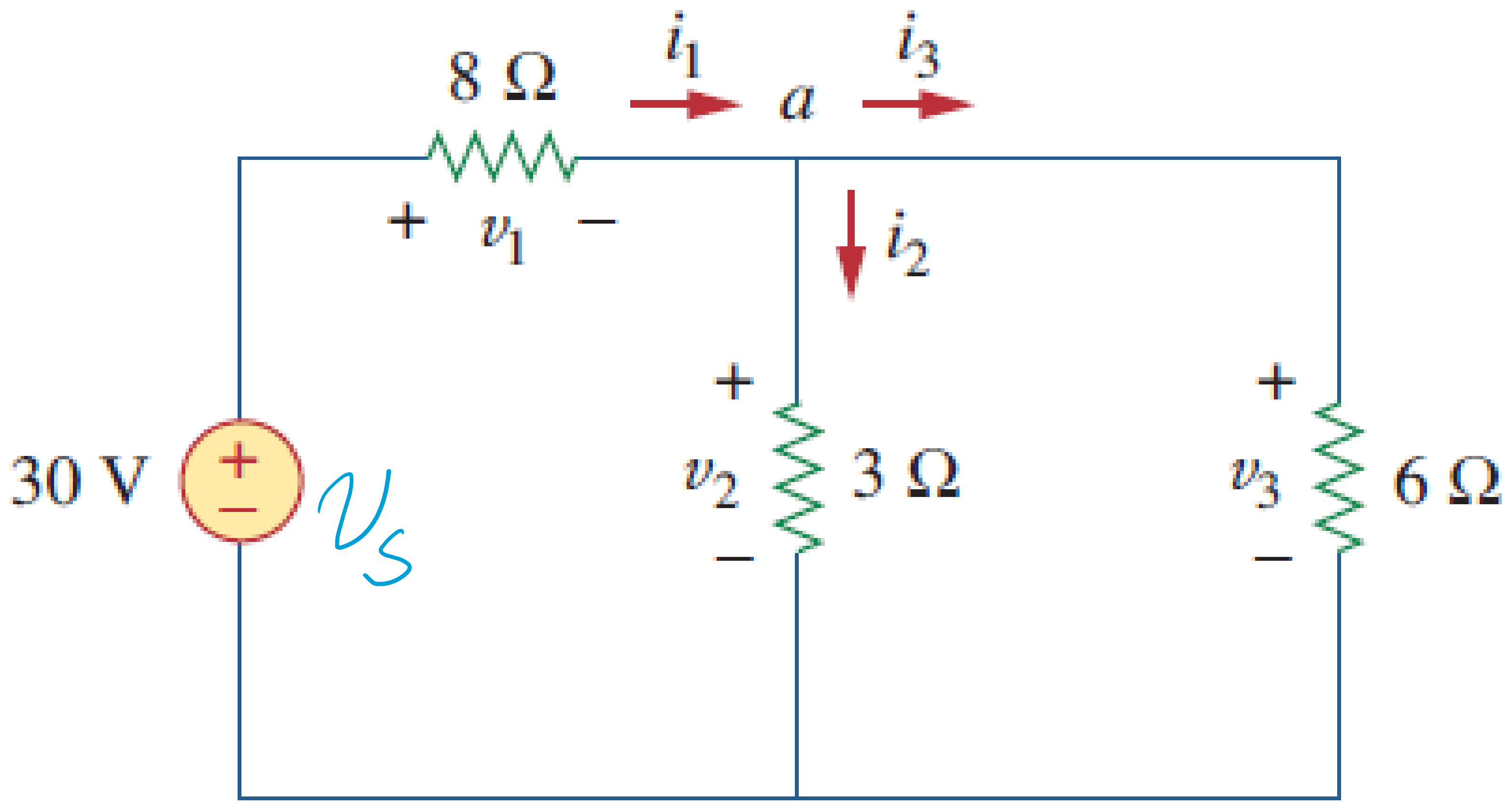


$$v_2 + v_3 + v_5 = v_1 + v_4$$

Exercise 2



Exercise 2



KVL:

$\sum v = 0$

$v_s = v_1 + v_2$ (1)

$v_2 = v_3$

$v_1 = 24V$

KCL:

$i_1 = i_2 + i_3$

$i_1 = \frac{v_2}{3} + \frac{v_2}{6}$ (2)

$\therefore i_2 = 2A, \; i_3 = 1A$

$\therefore i_1 = 3A$

from (1) and (2)

$v_s = 8\left(\frac{v_2}{3} + \frac{v_2}{6}\right) + v_2$

$30 = \frac{16 v_2}{6} + \frac{8 v_2}{6} + \frac{6 v_2}{6}$

$v_2 = \frac{30 \times 6}{30} = 6\ V = v_3$

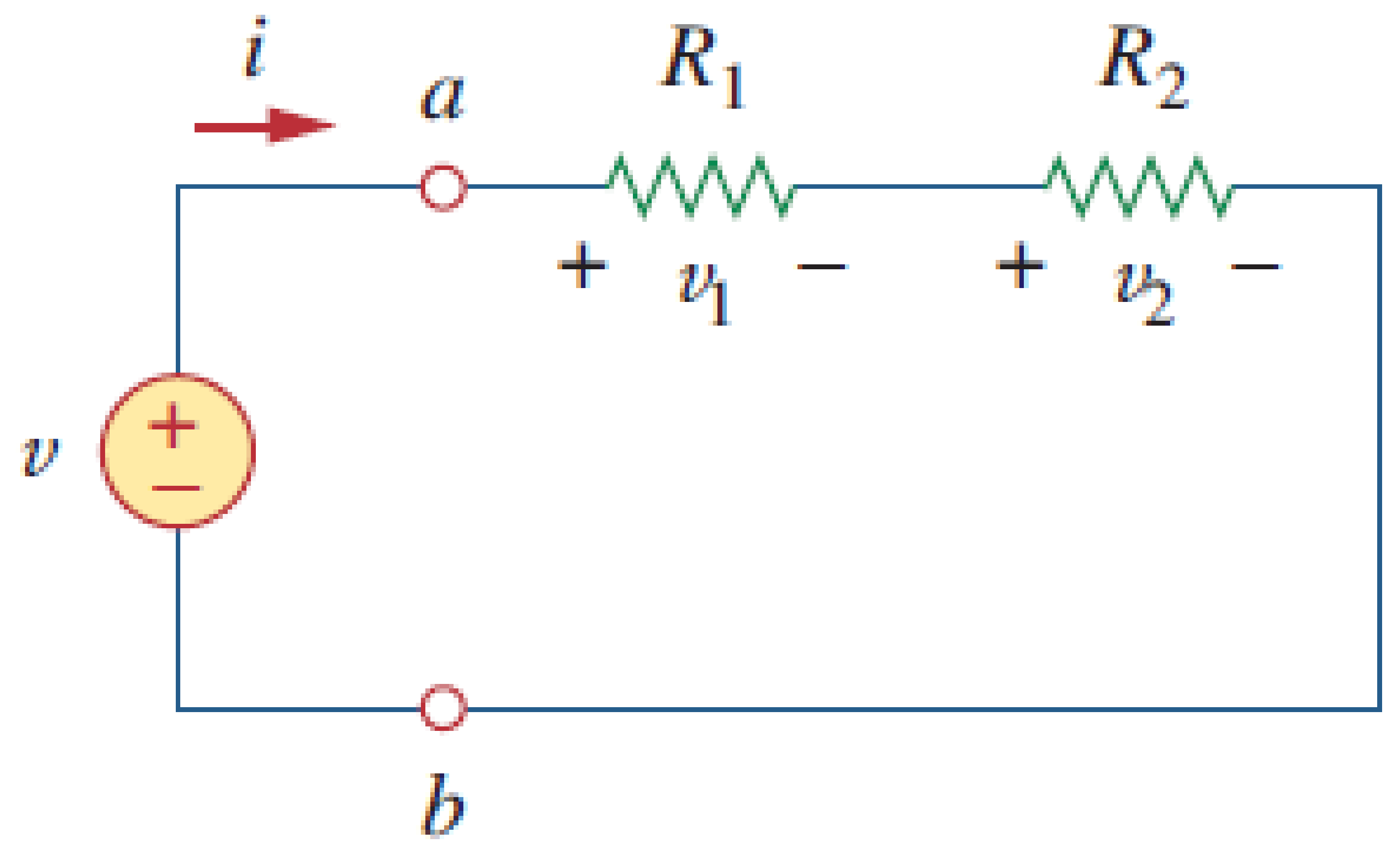
Series Resistors

$$v = v_1 + v_2$$

$$i(R_{eq}) = iR_1 + iR_2$$

$$i R_{eq} = i(R_1 + R_2)$$

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



$$R_{eq} = R_1 + R_2 + \cdots + R_N = \sum_{n=1}^{N} R_n$$

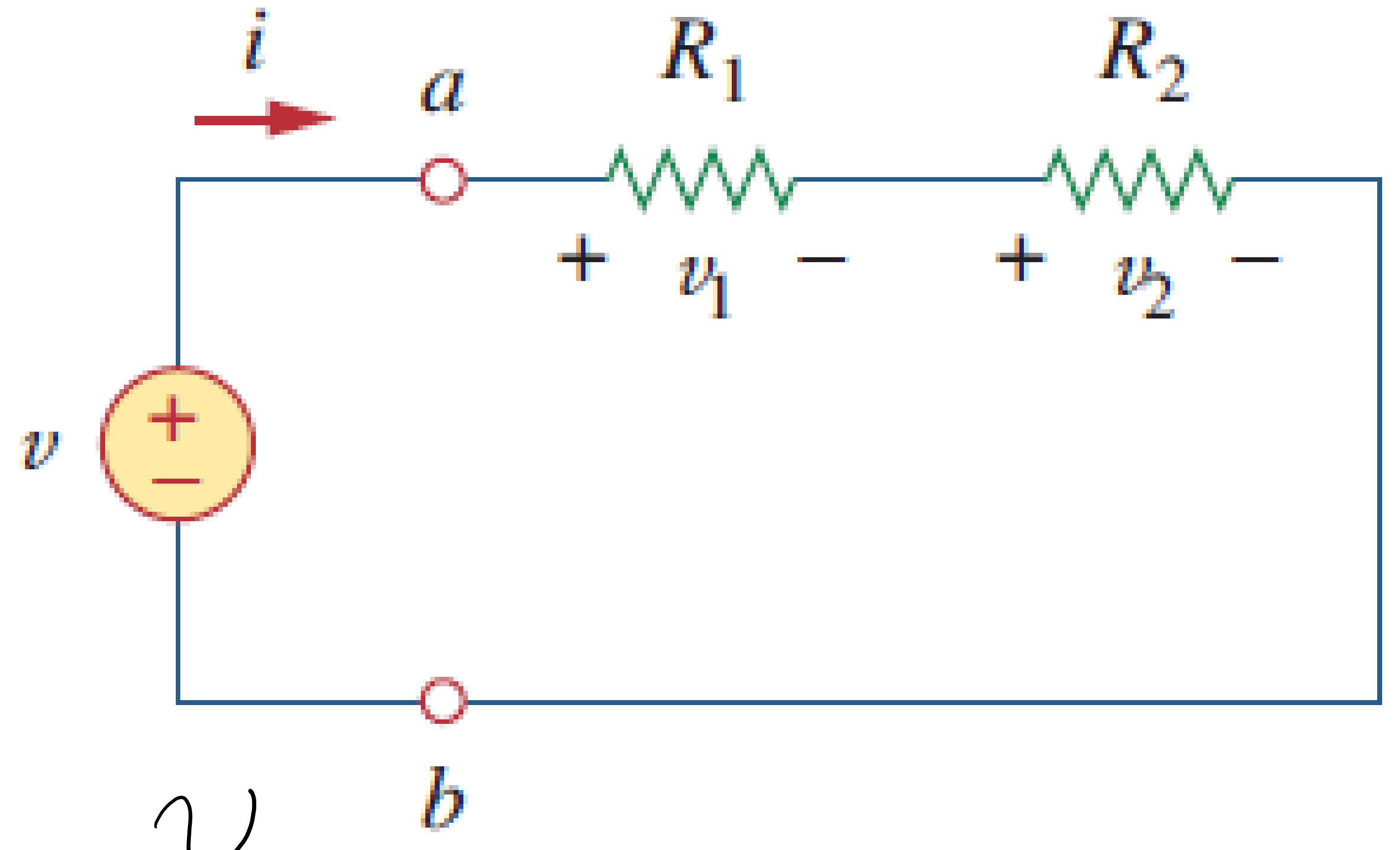
Voltage Division

$$v = i(R_1 + R_2)$$

$$\therefore i = \frac{v}{R_1 + R_2} \longrightarrow (1)$$

$$v_1 = iR_1$$

$$\therefore i = \frac{v_1}{R_1} \longrightarrow 2$$

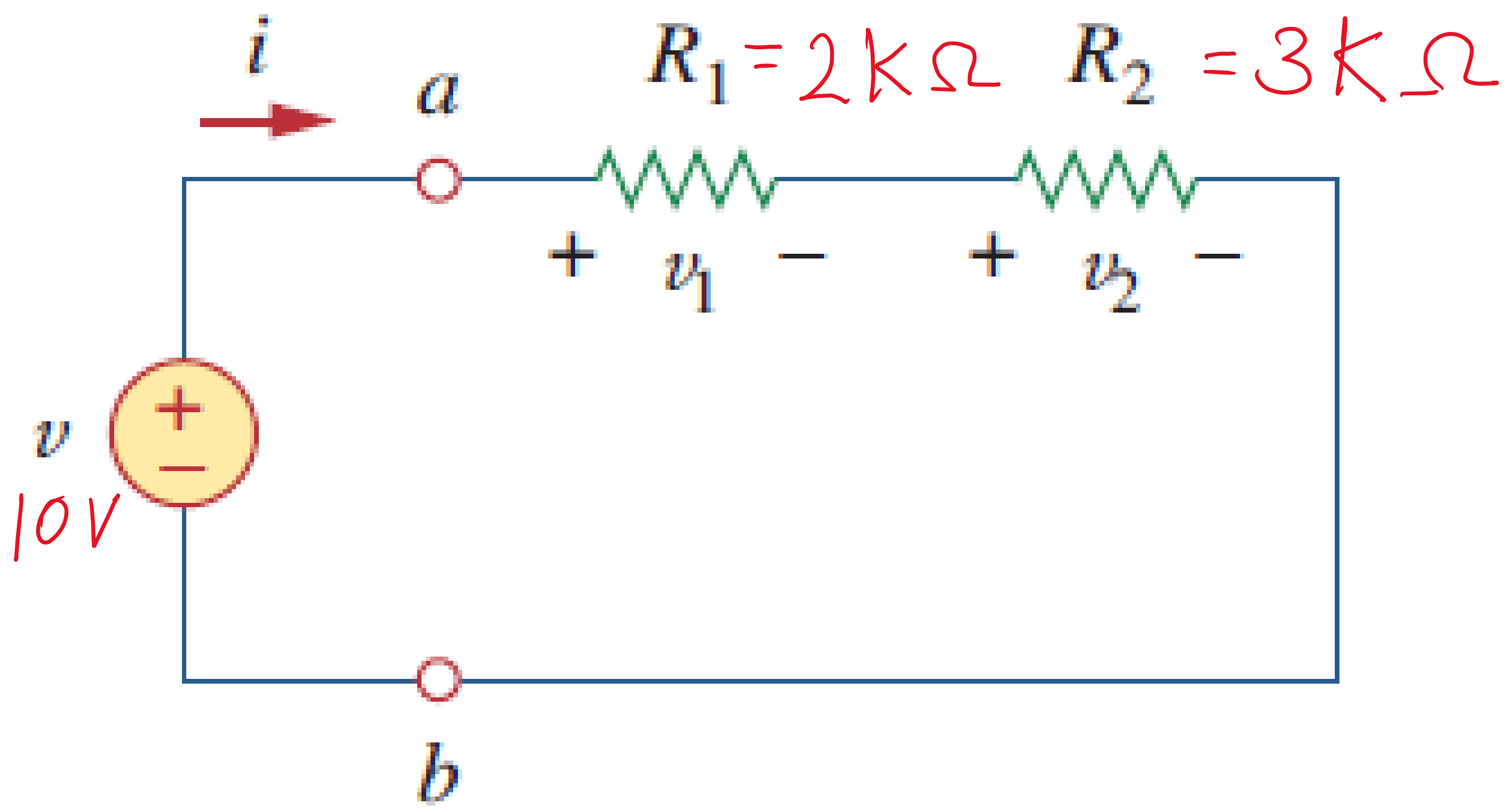


from (1) & (2) : $\frac{v_1}{R_1} = \frac{v}{R_1 + R_2}$

$$v_1 = \frac{R_1}{R_1 + R_2} v$$

Voltage Division

Find v_1 ?!



Parallel Resistors

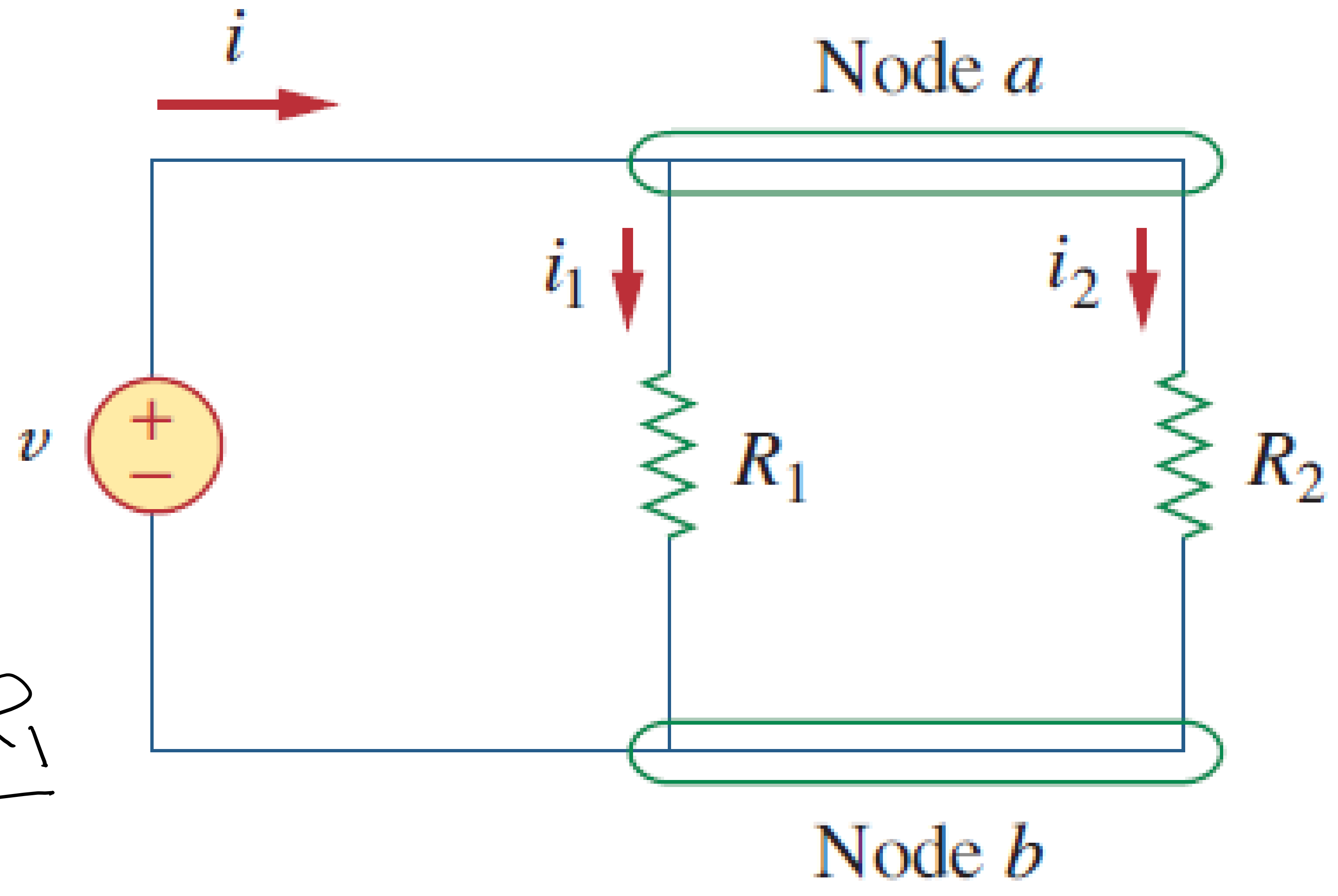
@ Node a : $\sum i = 0$;

$$i = i_1 + i_2$$

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

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

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



Current Division

$$i_1 = \frac{v}{R_1} \Rightarrow v = i_1 R_1 \rightarrow (1)$$

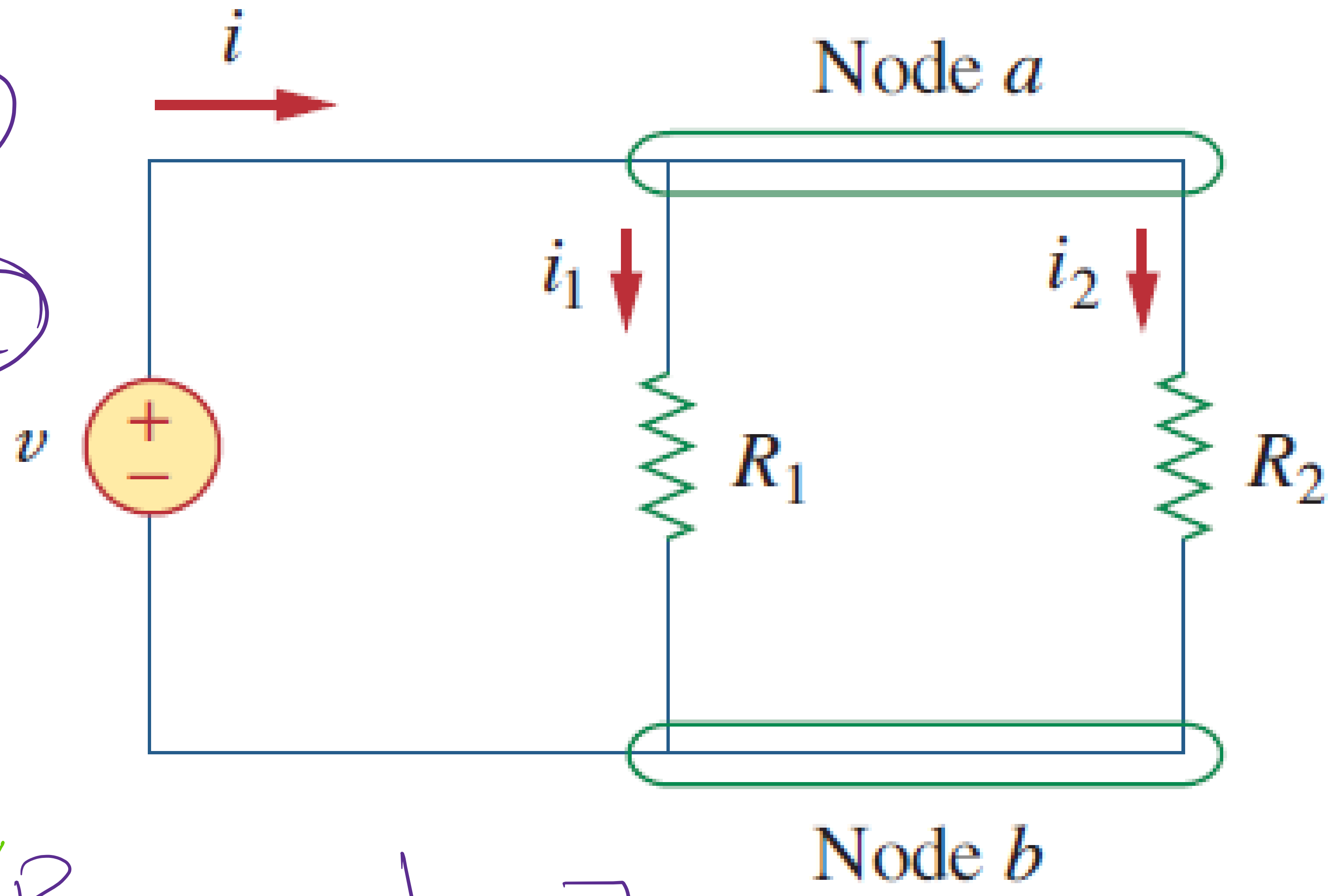
$$i = \frac{v}{R_{eq}} \Rightarrow v = i R_{eq} \rightarrow (2)$$

from (1) and (2)

$$\therefore i_1 R_1 = i R_{eq}$$

$$i_1 = i \frac{R_{eq}}{R_1} = i \left[\frac{R_1 R_2}{R_1 + R_2} \cdot \frac{1}{R_1} \right]$$

$$i_1 = i \left[\frac{R_2}{R_1 + R_2} \right]$$



Exercise 3

2.10 In the circuit of Fig. 2.67, a decrease in R_3 leads to a decrease of, select all that apply:

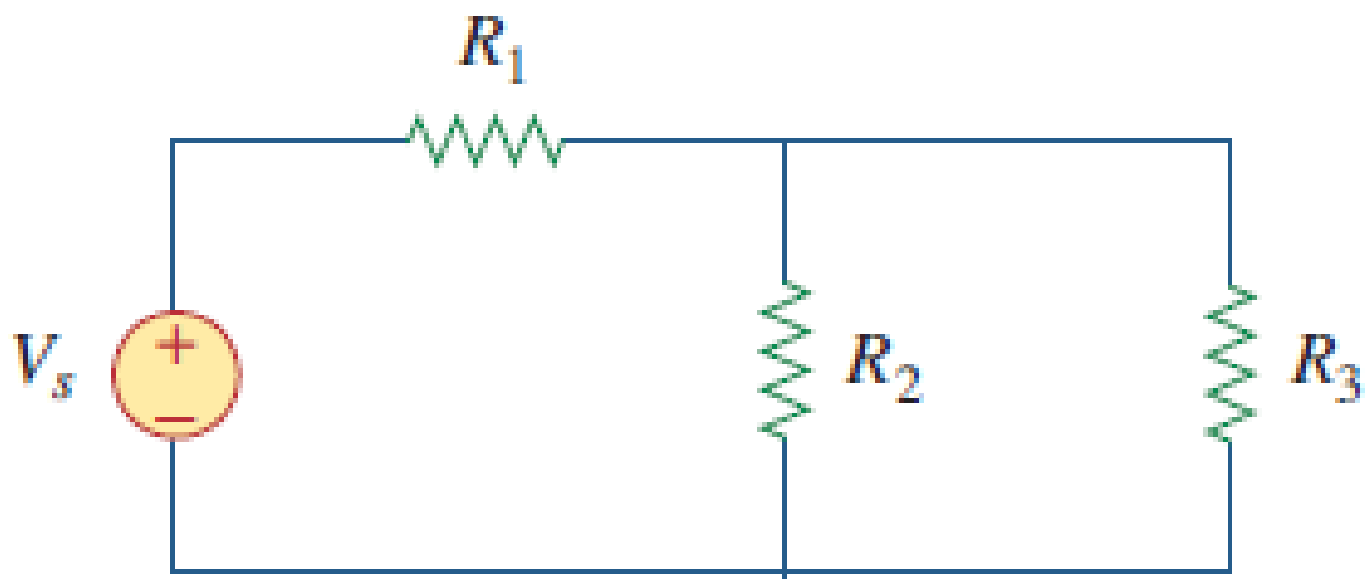
(a) current through R_3

(b) voltage across R_3

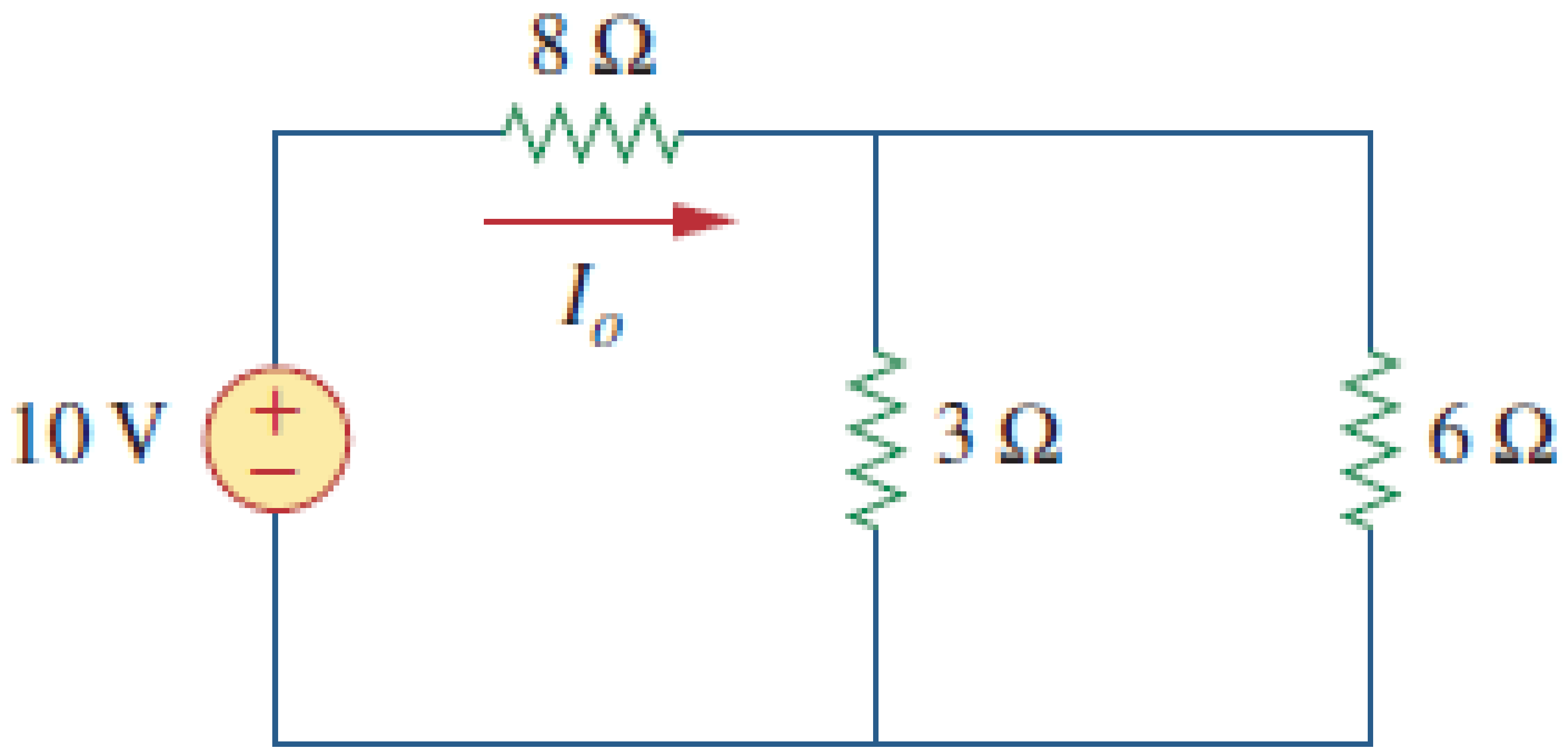
(c) voltage across R_1

(d) power dissipated in R_2

(e) none of the above



Exercise 4



Thank you