BEEE101L
Basic Electrical Engineering

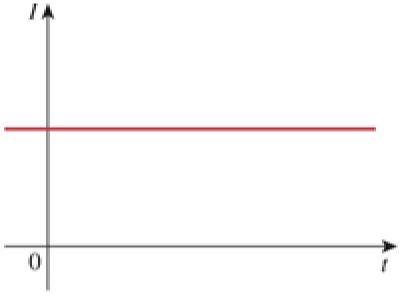
L	T	P	J	C
2	0	0	0	2

Unit I

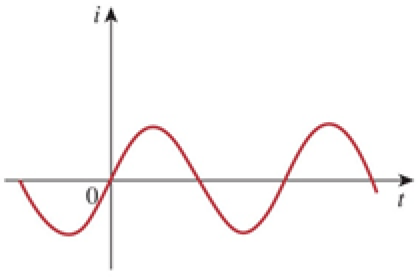
- **DC circuits:** Basic circuit elements and sources; Ohms law, Kirchhoff’s laws; Series and parallel connection of circuit elements; Source transformation; Node voltage analysis; Mesh current analysis; Maximum power transfer theorem.

DC circuits

- A current that remains constant with time is called Direct Current (DC)
- Such current is represented by the capital *I*, time varying current uses the lowercase, *i*.
- A common source of DC is a battery.
- A current that varies sinusoidally with time is called Alternating Current (AC)
- Mains power is an example of AC



(a)



(b)

Systems of UNITS

Quantity	Basic Unit	Symbol
Length	**meter**	**m**
Mass	**kilogram**	**kg**
Time	**second**	**s**
Electric current	**ampere**	**A**
Thermodynamic Temperature	**kelvin**	**K**
Luminous intensity	**candela**	**cd**

The SI Prefixes

- Prefixes on SI units allow for easy relationships between large and small values

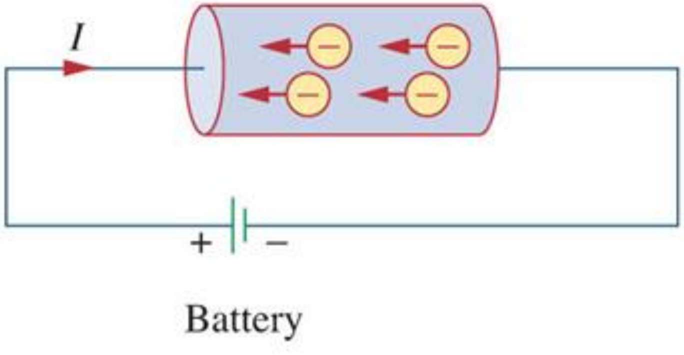
Multiplier	Prefix	Symbol
10^{18}	exa	E
10^{15}	peta	P
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hecto	h
10	deka	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a

Charge

- **Charge** is a basic SI unit, measured in **Coulombs** (C)
- Charge of single electron is $1.602*10^{-19}$ C
- One Coulomb is quite large, $6.24*10^{18}$ electrons.
- In the lab, one typically sees (pC, nC, or μC)
- Charge is always multiple of electron charge
- Charge cannot be created or destroyed, only transferred.

Electric Current

- The movement of charge is called a current
- Historically the moving charges were thought to be positive
- Thus we always note the direction of the equivalent positive charges, even if the moving charges are negative.



Electric Current

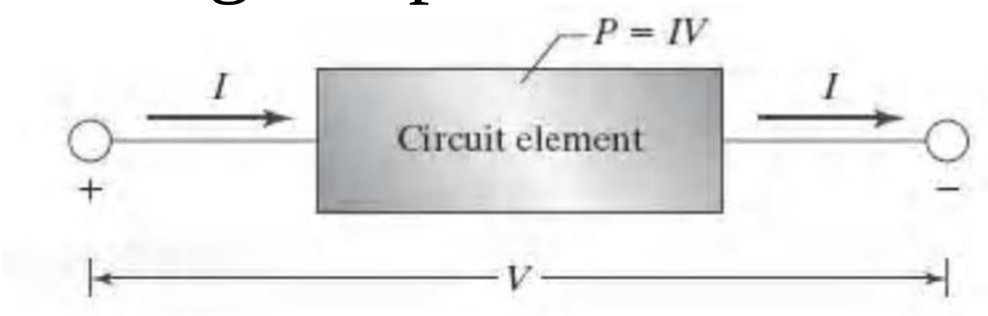
- Current, i, is measured as charge moved per unit time through an element.

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

- Unit is Ampere (A), is one Coulomb/second
- A positive current through a component is the same as a negative current flowing in the opposite direction.

The passive sign convention

- When we observe that positive current enters the positive terminal of a component, we say that the component obeys the passive sign convention (PSC).
- Therefore, when the passive sign convention is being obeyed, it indicates that a component is dissipating energy (or power) as charge is being displaced from a higher potential to a lower potential.



Voltage

- Electrons move when there is a difference in charge between two locations.
- This difference is expressed at the potential difference, or voltage (V).
- It is always expressed with reference to two locations.
- It is equal to the energy needed to move a unit charge between the locations.
- Positive charge moving from a higher potential to a lower yields energy.
- Moving from negative to positive requires energy.

Power

- Power: time rate of expending or absorbing energy
- Denoted by *p*
- Circuit Elements that *absorb power* have a positive value of *p*
- Circuit Elements that *produce power* have a negative value of *p*

$$p = \frac{dw}{dt} \qquad p = \mp vi$$

$p =$ power in watts (W = J/s)
$w =$ energy in joules (J)
$t =$ time in seconds (s)
$v =$ voltage in volts (V)
$i =$ current in amperes (A)

Typical average monthly consumption of household appliances.

Appliance	kWh consumed	Appliance	kWh consumed
Water heater	500	Washing machine	120
Freezer	100	Stove	100
Lighting	100	Dryer	80
Dishwasher	35	Microwave oven	25
Electric iron	15	Personal computer	12
TV	10	Radio	8
Toaster	4	Clock	2

Energy

- *Law of Conservation of Energy*: the net power absorbed by a circuit is equal to 0.
- In other words, the total energy produced in a circuit is equal to the total energy absorbed
- *Energy*: capacity to do work, measured in joules (J)

$$w = \int_{t_0}^{t} p\,dt = \int_{t_0}^{t} (\pm vi)\,dt$$

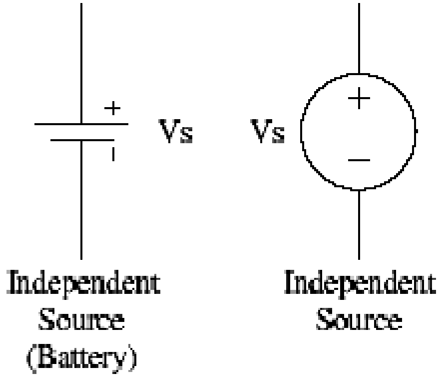
If current and voltage are constant (DC),

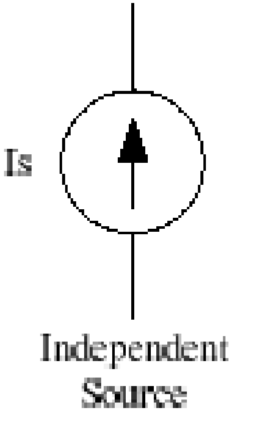
$$w = \int_{t_0}^{t} p\,dt = p(t - t_0)$$

Circuit Elements

- **Ideal Independent Source:** provides an active element with specified voltage or current that is completely independent of other circuit variables
- **Ideal Independent**

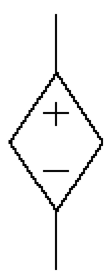
Voltage Source: **Current Source**

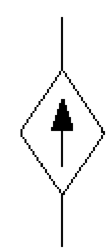




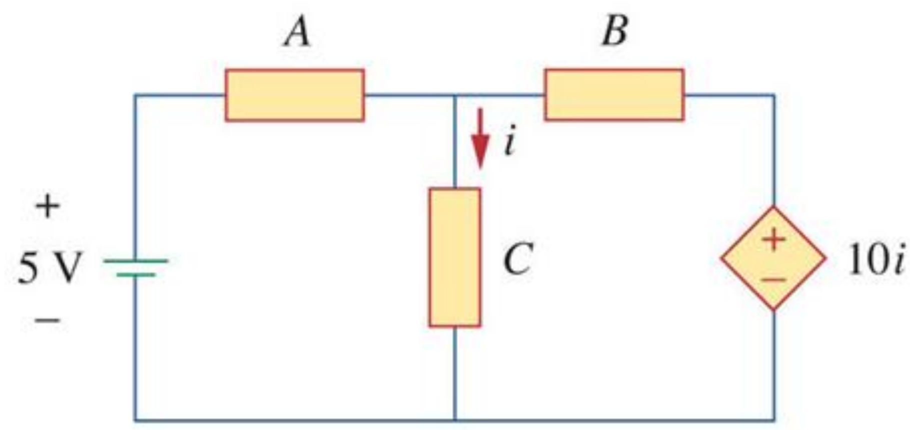
Circuit Elements

- An ideal dependent (or controlled) source is an active element in which the source quantity is controlled by another voltage or current.
- Diamond symbols
- Ideal dependent voltage source
- Current source



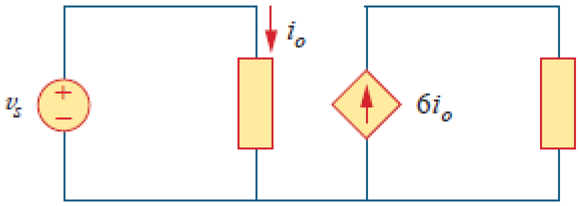


Dependent Source example



- Types:

1. A Voltage Controlled Voltage Source (VCVS)
2. A Current Controlled Voltage Source (CCVS)
3. A Voltage Controlled Current Source(VCCS)
4. A Current Controlled Current Source(CCCS)

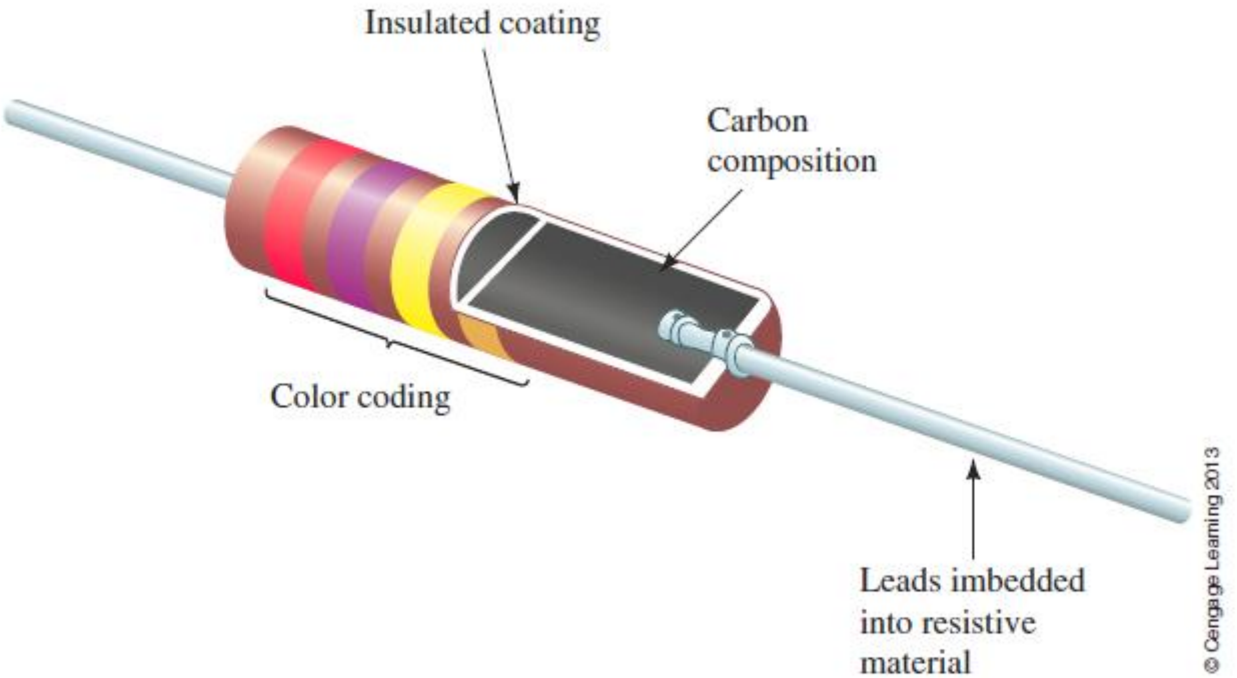


i_o
v_s
+
−
$6i_o$

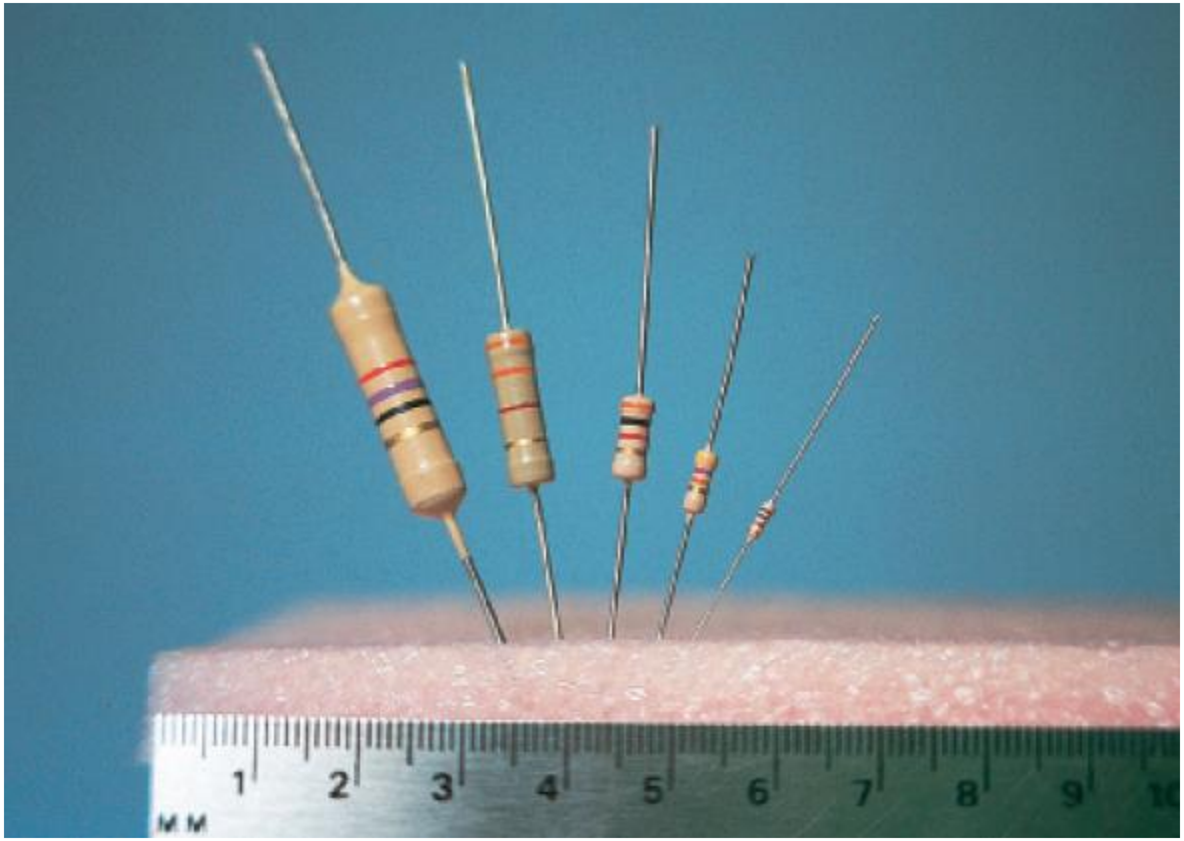
Basic circuit Elements

- Resistors
- Inductors
- Capacitors

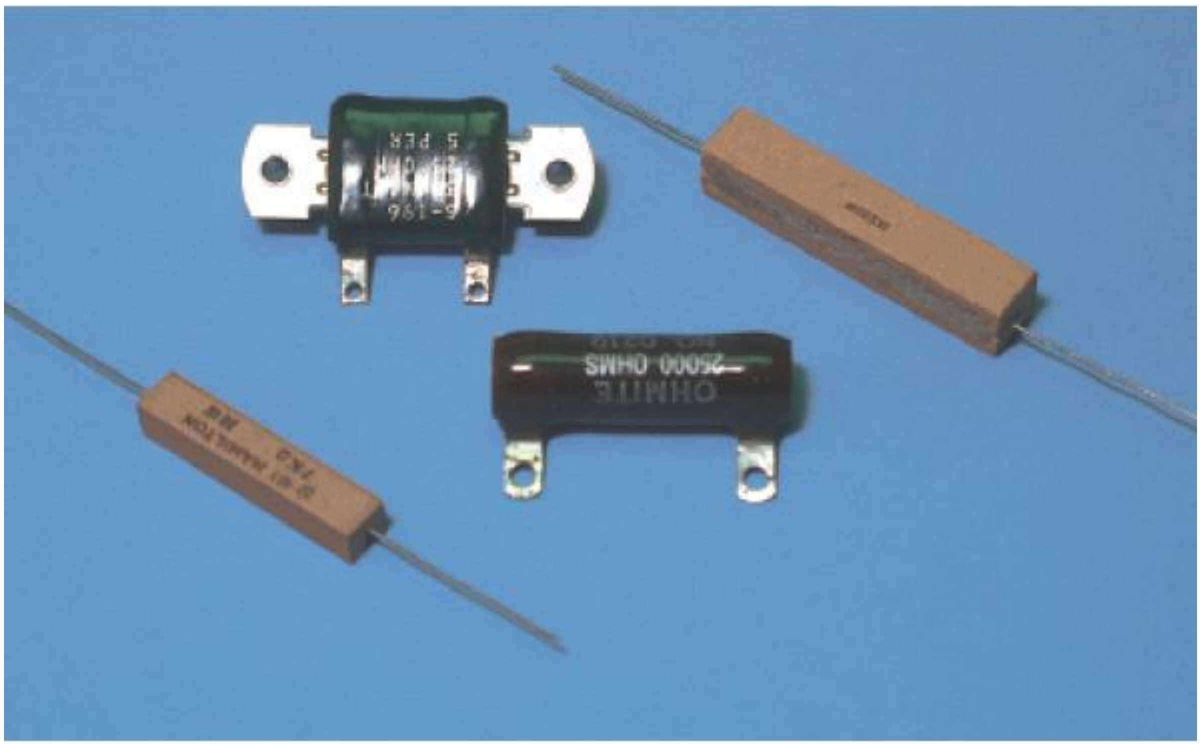
Structure of carbon composition resistor



Size- 2W, 1W, 1/2W, 1/4W, 1/8W



Power resistors

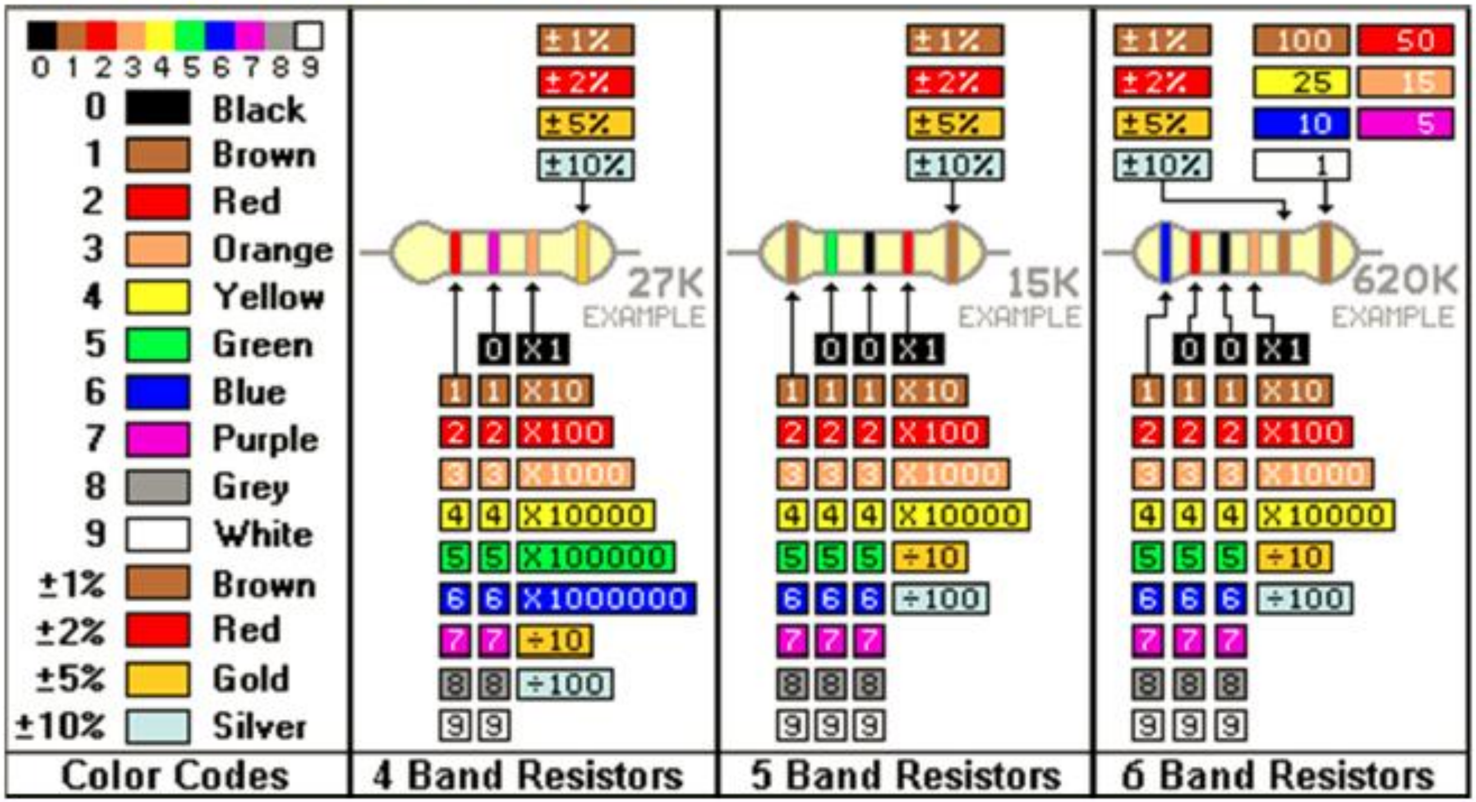


Variable resistor

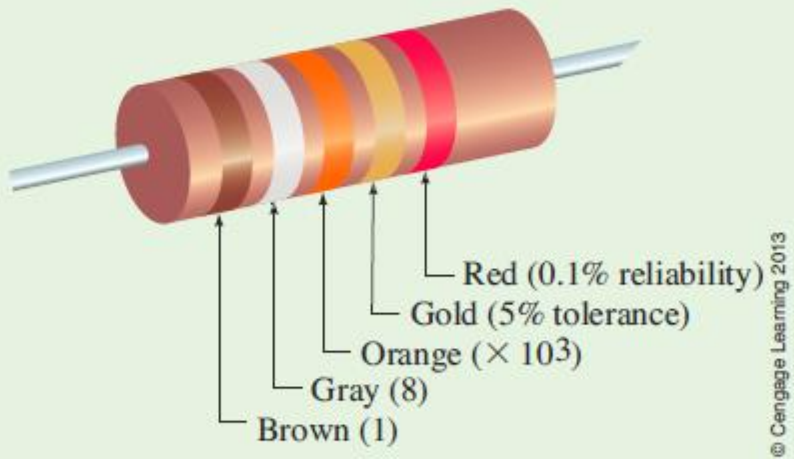
(a) External view of variable resistors

(b) Internal view of variable resistor

- **Component values**



Determine the resistance of a carbon film resistor having the color codes shown in Figure 3–17.

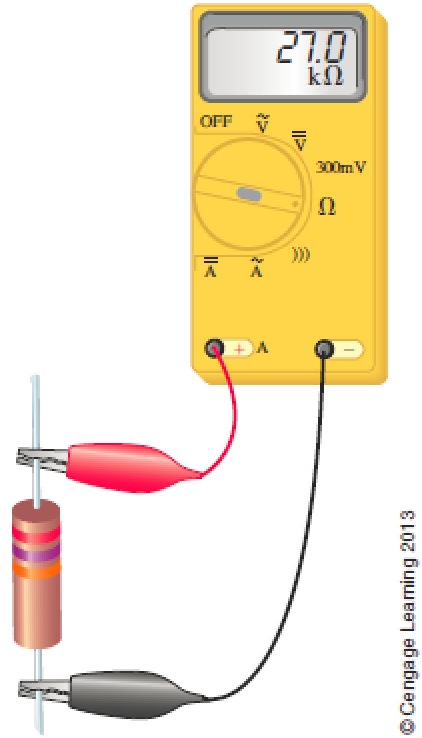


From Table, we see that the resistor will have a value determined as

R = 18 x 103 ohm ±5%

= 18 k ± 0.9 k with a reliability of 0.1%

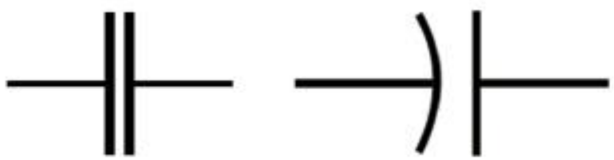
Digital multimeter. To measure ohms, set the dial to Ω .

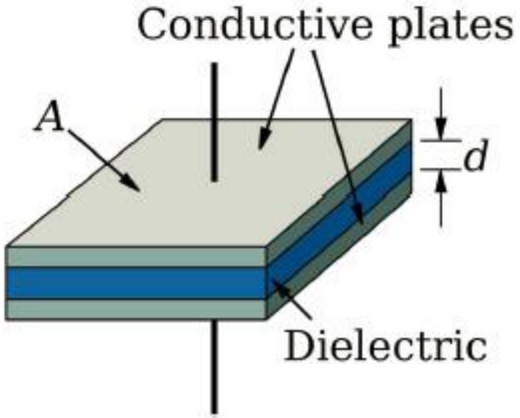


Ohmmeter used to measure an isolated component.

Capacitor / Capacitance (C - Farads)

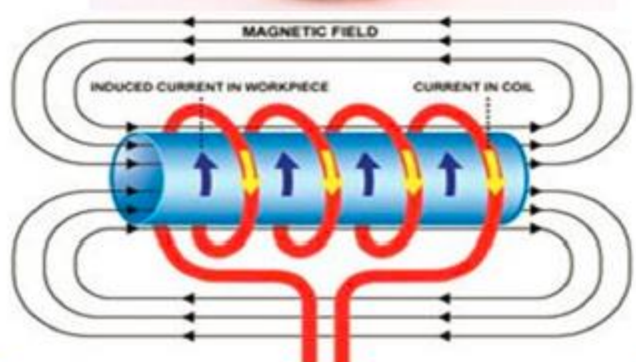
The property of being able to store electric charge

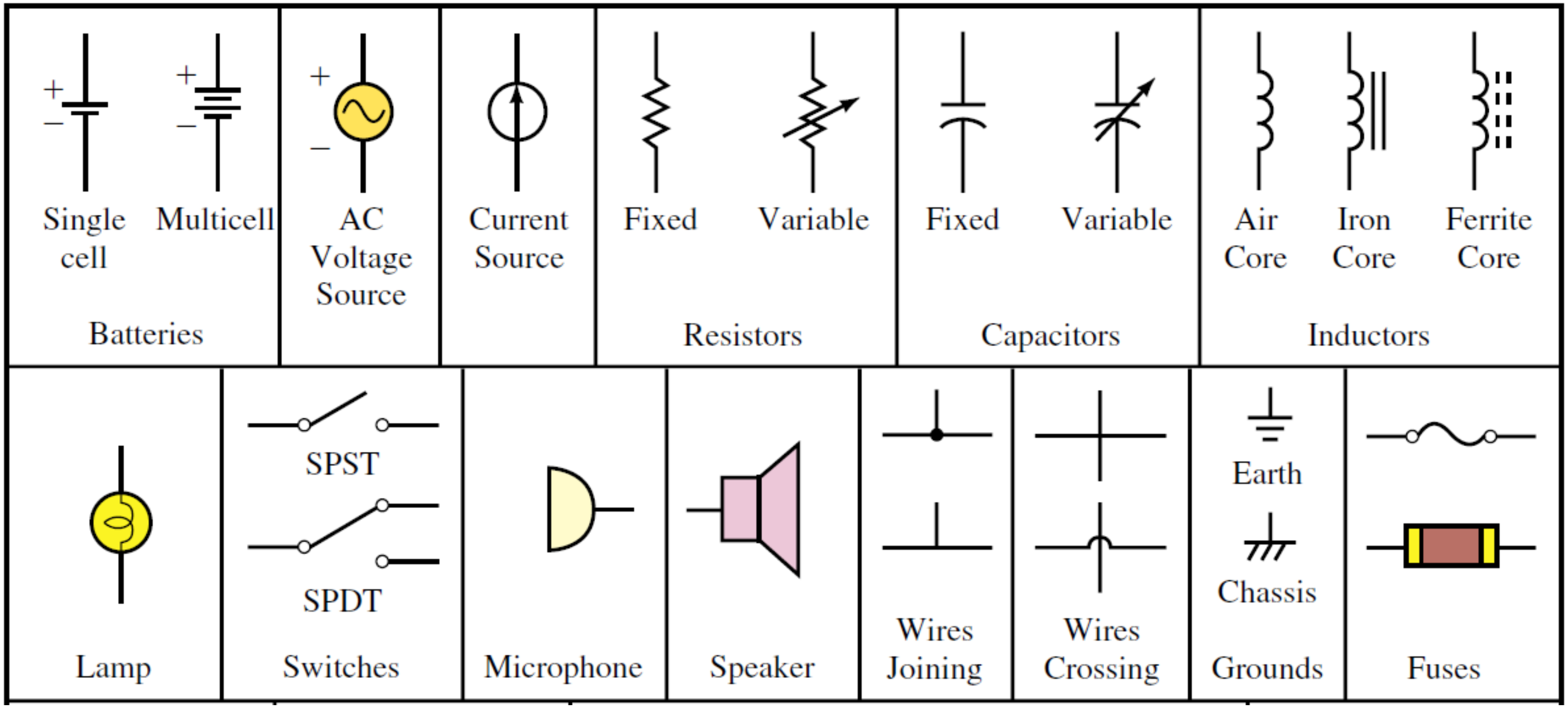


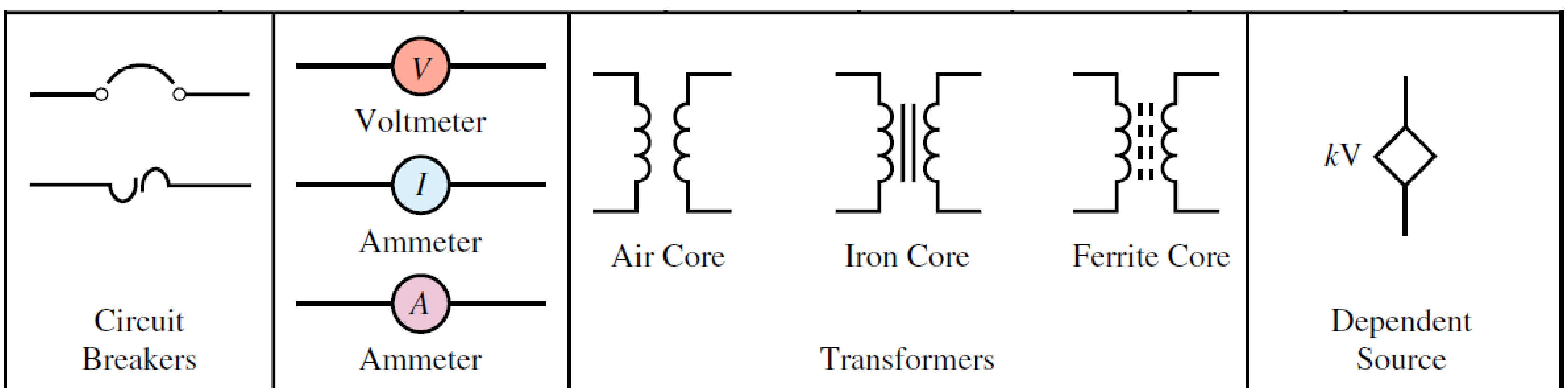


Inductor / Inductance (L - Henrys)

The property of a circuit by which a change in current induces an electromotive force by electro-magnetic induction.




+
−
Single cell
Multicell
Batteries
AC Voltage Source
Current Source
Fixed
Variable
Resistors
Fixed
Variable
Capacitors
Air Core
Iron Core
Ferrite Core
Inductors
Lamp
SPST
SPDT
Switches
Microphone
Speaker
Wires Joining
Wires Crossing
Earth
Chassis
Grounds
Fuses


Circuit Breakers
V
Voltmeter
I
Ammeter
A
Ammeter
Air Core
Iron Core
Ferrite Core
Transformers
kV
Dependent Source

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

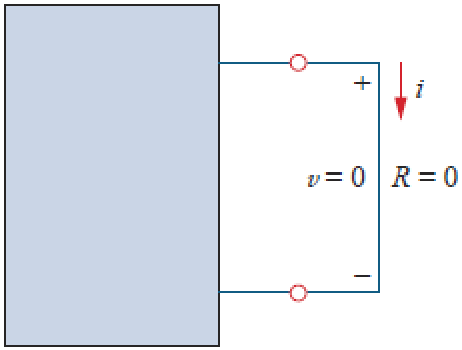
Resistivities of common materials.

Material	Resistivity ($\Omega\cdot$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
Glass	10^{12}	Insulator
Teflon	3×10^{12}	Insulator

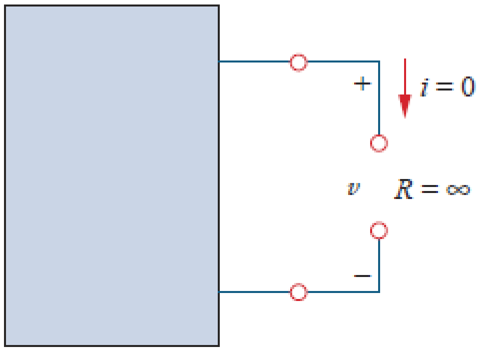
- **Georg Simon Ohm** (1787–1854), a German physicist, in 1826
- experimentally determined the most basic law relating voltage and current
- for a resistor. Ohm’s work was initially denied by critics.

- **Andre-Marie Ampere** (1775–1836), a French mathematician and
- physicist, laid the foundation of electrodynamics. He defined the electric
- current and developed a way to measure it in the 1820s.

- **Alessandro Antonio Volta** (1745–1827), an Italian physicist,
- invented the electric battery—which provided the first continuous flow
- of electricity—and the capacitor.



+
i
v = 0
R = 0
−

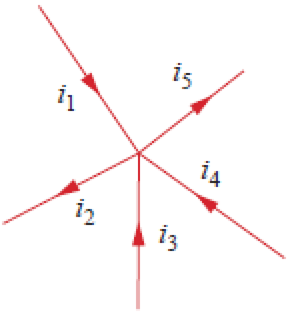


+
i = 0
v
R = ∞
−

Kirchhoff’s Laws

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

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

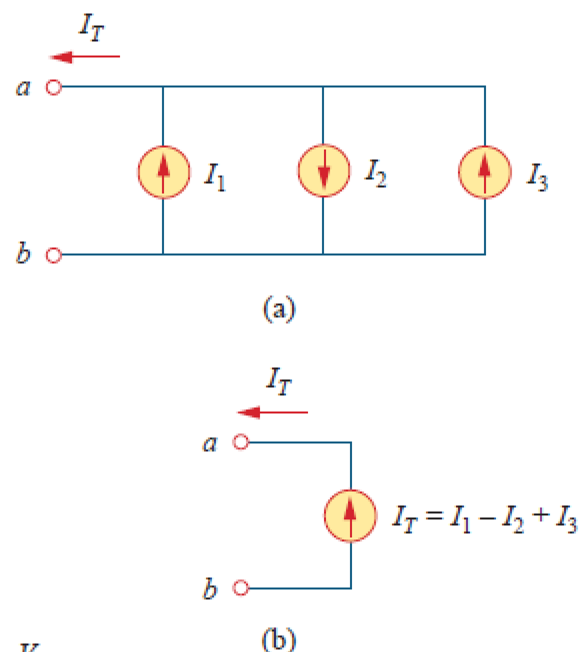


- **Gustav Robert Kirchhoff** (1824–1887), a German physicist, s
- two basic laws in 1847 concerning the relationship between the c
- and voltages in an electrical network. Kirchhoff’s laws, along
- with Ohm’s law, form the basis of circuit theory.

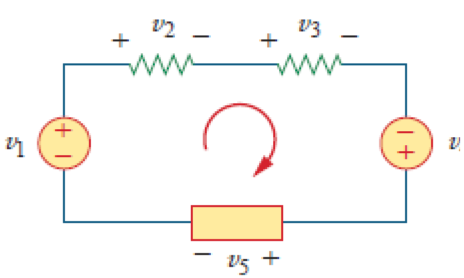
Kirchhoff’s Laws

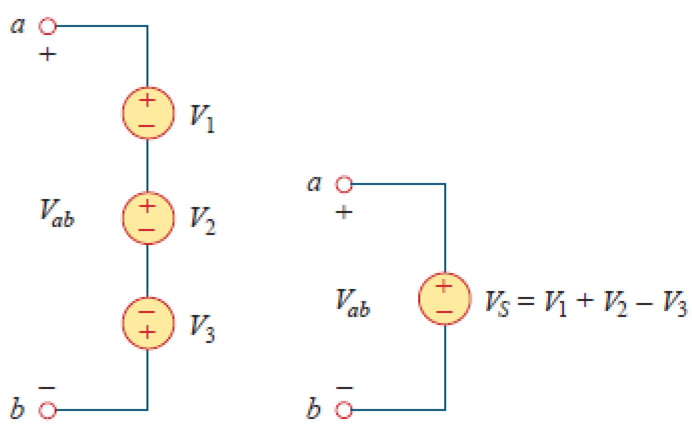
- Kirchhoff’s voltage law (KVL) states that the algebraic sum of all voltages around a closed path (or loop) is zero.

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



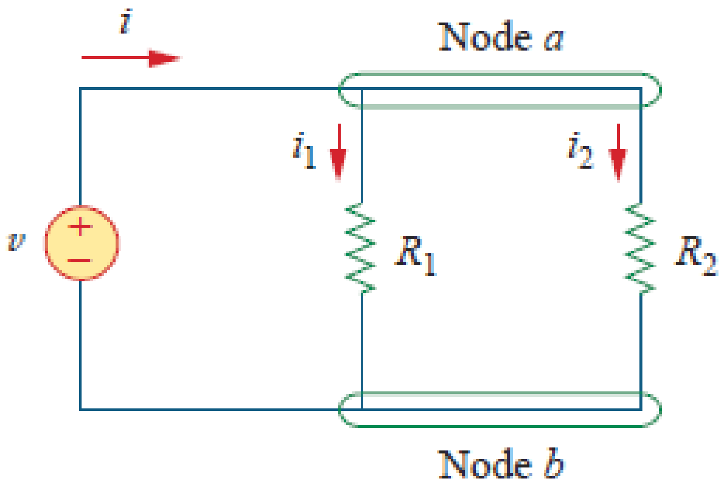
- Sum of voltage drops= Sum of voltage rises



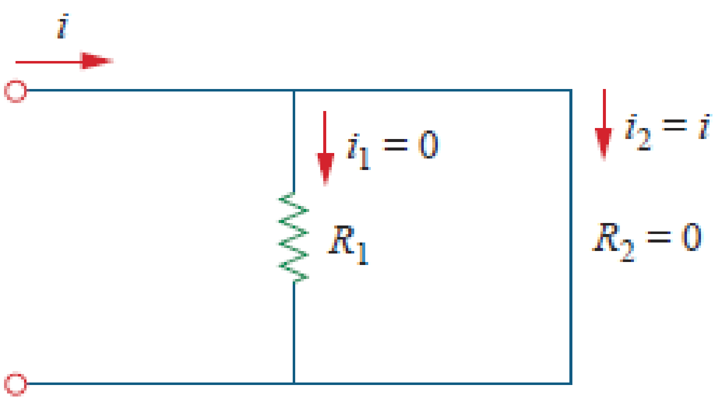


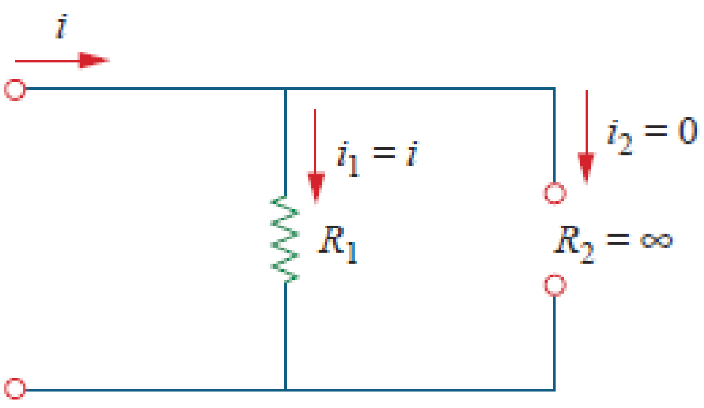
(a) (b)

Current division

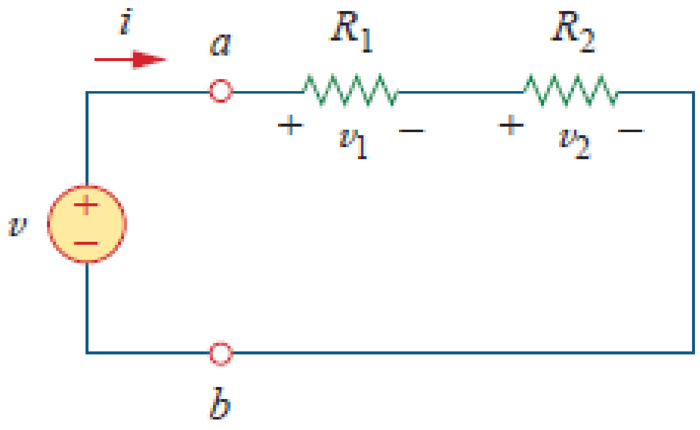


$$i_1 = \frac{R_2\, i}{R_1 + R_2}, \qquad i_2 = \frac{R_1\, i}{R_1 + R_2}$$



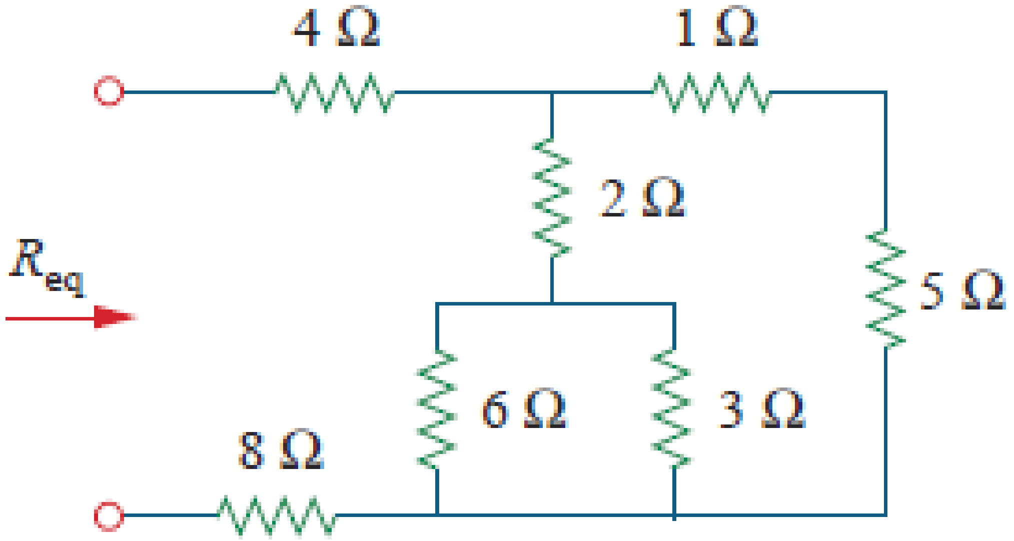


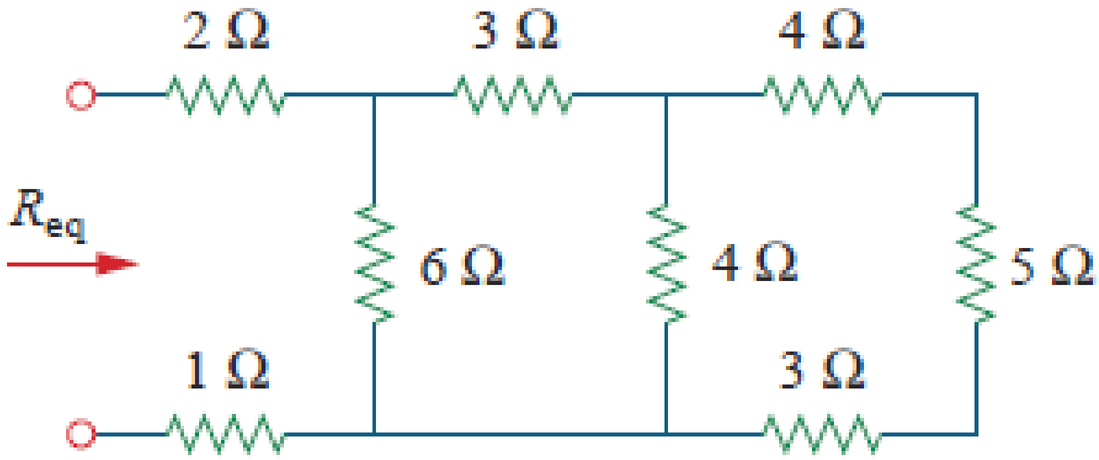
Voltage division

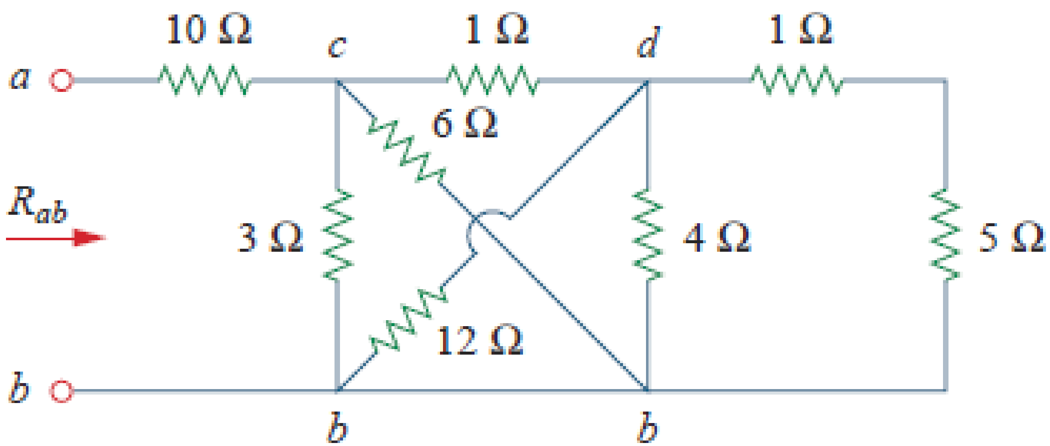


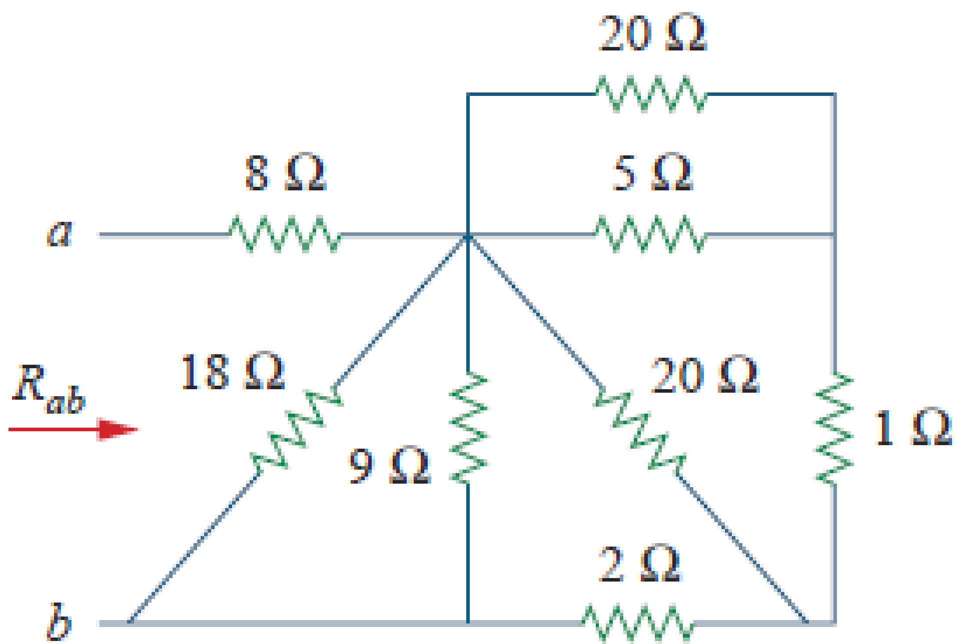
$$v_1 = \frac{R_1}{R_1 + R_2} v, \qquad v_2 = \frac{R_2}{R_1 + R_2} v$$

Problems

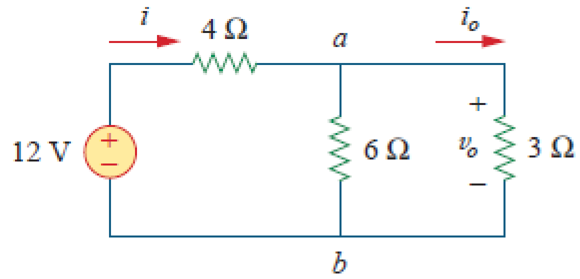




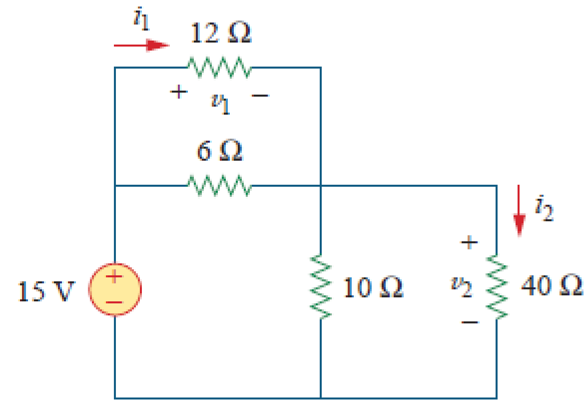

10 Ω
c
1 Ω
d
1 Ω
a
6 Ω
Rab
3 Ω
4 Ω
5 Ω
12 Ω
b
b
b


20 Ω
8 Ω
5 Ω
a
18 Ω
Rab
20 Ω
1 Ω
9 Ω
2 Ω
b

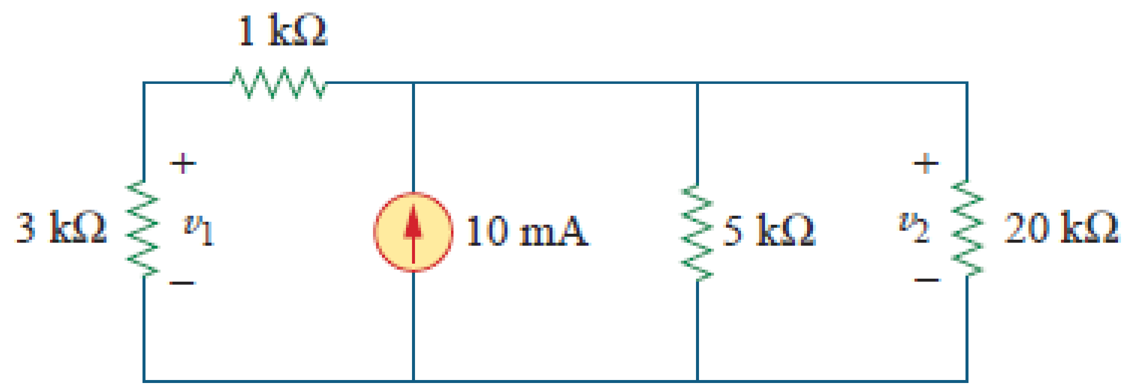
- Find the power across 3 ohm resistor



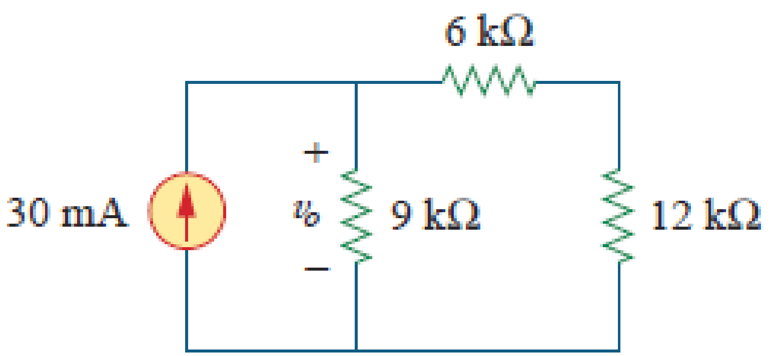
- Find current, voltage and power across all the elements.



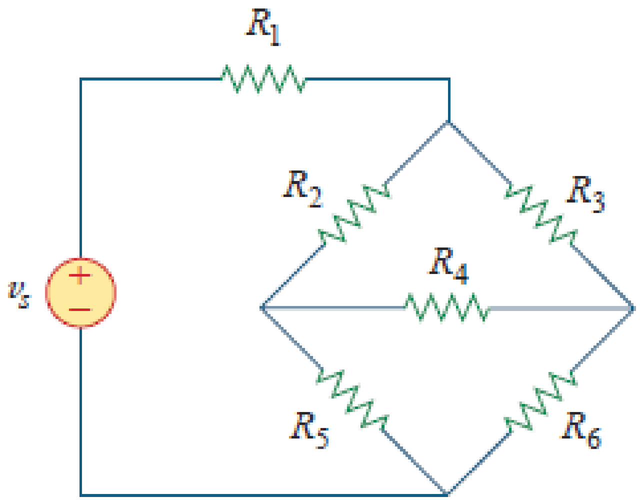
- find: (a) and (b) the power dissipated in the 3-k and 20-k resistors, and (c) the power supplied by the current source.

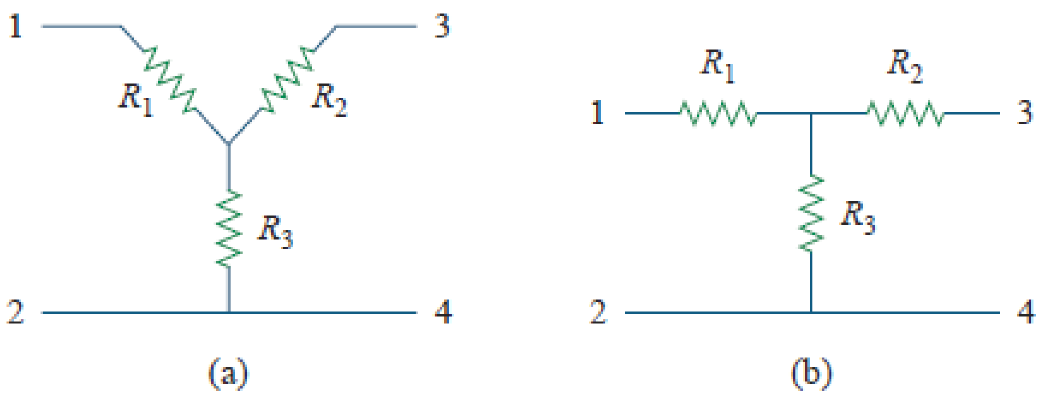


- Find (a) the voltage vo (b) the power supplied by the current source, (c) the power absorbed by each resistor.
-

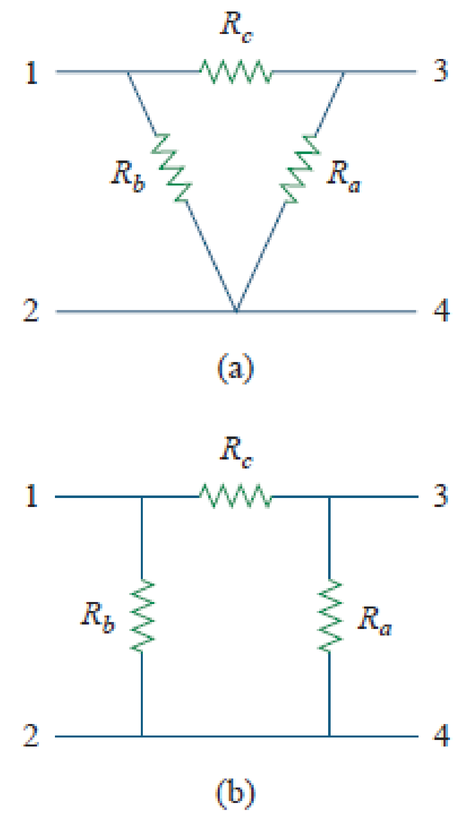


Wye-Delta Transformations





Two forms of the same network: (a) Y, (b) T.



Two forms of the same network: (a) Δ, (b) Π.

$$R_{12}(\mathrm{Y}) = R_1 + R_3$$

$$R_{12}(\Delta) = R_b \parallel (R_a + R_c)$$

Setting $R_{12}(\mathrm{Y}) = R_{12}(\Delta)$ gives

$$R_{12} = R_1 + R_3 = \frac{R_b(R_a + R_c)}{R_a + R_b + R_c}$$

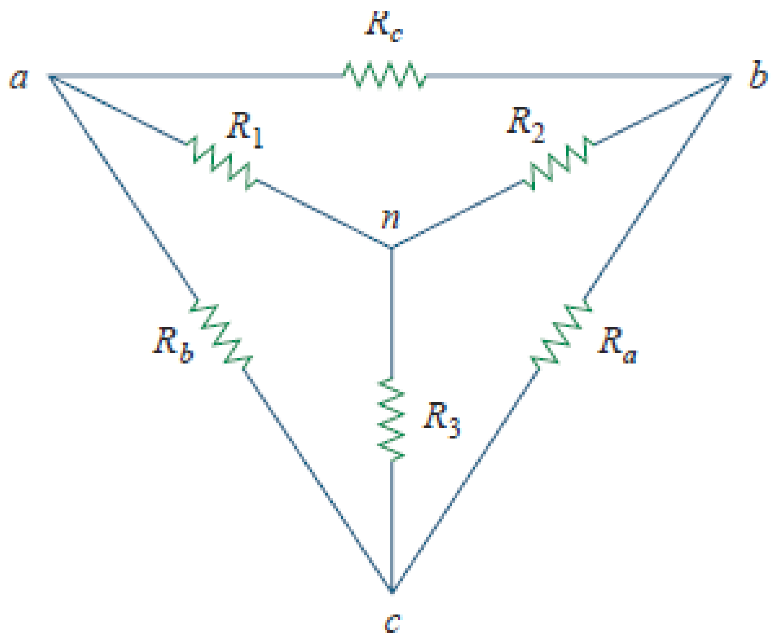
Similarly,

$$R_{13} = R_1 + R_2 = \frac{R_c(R_a + R_b)}{R_a + R_b + R_c}$$

$$R_{34} = R_2 + R_3 = \frac{R_a(R_b + R_c)}{R_a + R_b + R_c}$$

$$R_1 - R_2 = \frac{R_c(R_b - R_a)}{R_a + R_b + R_c}$$

$$\boxed{R_1 = \frac{R_b R_c}{R_a + R_b + R_c}} \qquad \boxed{R_2 = \frac{R_c R_a}{R_a + R_b + R_c}} \qquad \boxed{R_3 = \frac{R_a R_b}{R_a + R_b + R_c}}$$



Each resistor in the Y network is the product of the resistors in the two adjacent Δ branches, divided by the sum of the three Δ resistors.

Wye to Delta Conversion

$$R_1R_2 + R_2R_3 + R_3R_1 = \frac{R_aR_bR_c(R_a + R_b + R_c)}{(R_a + R_b + R_c)^2}$$

$$= \frac{R_aR_bR_c}{R_a + R_b + R_c}$$

$$\boxed{R_a = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_1}}$$

$$\boxed{R_b = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_2}}$$

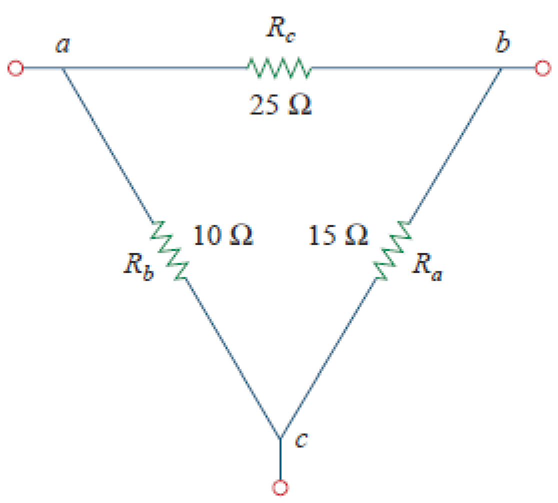
$$\boxed{R_c = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_3}}$$

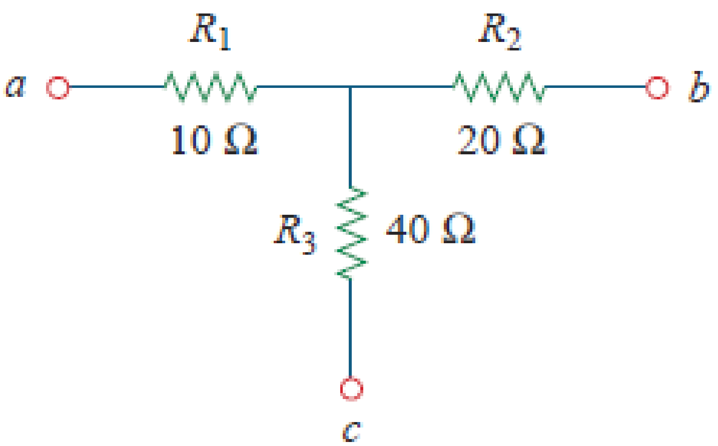
The Y and Δ networks are said to be *balanced* when

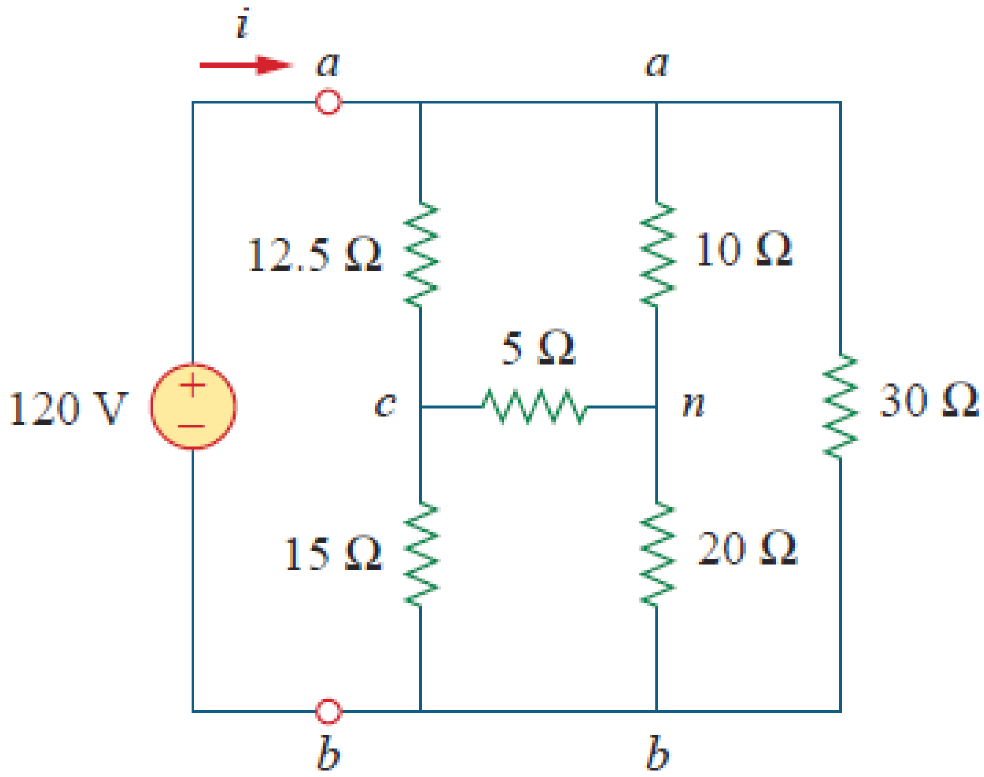
$$R_1 = R_2 = R_3 = R_Y, \qquad R_a = R_b = R_c = R_\Delta$$

$$\boxed{R_Y = \frac{R_\Delta}{3} \qquad \text{or} \qquad R_\Delta = 3R_Y}$$

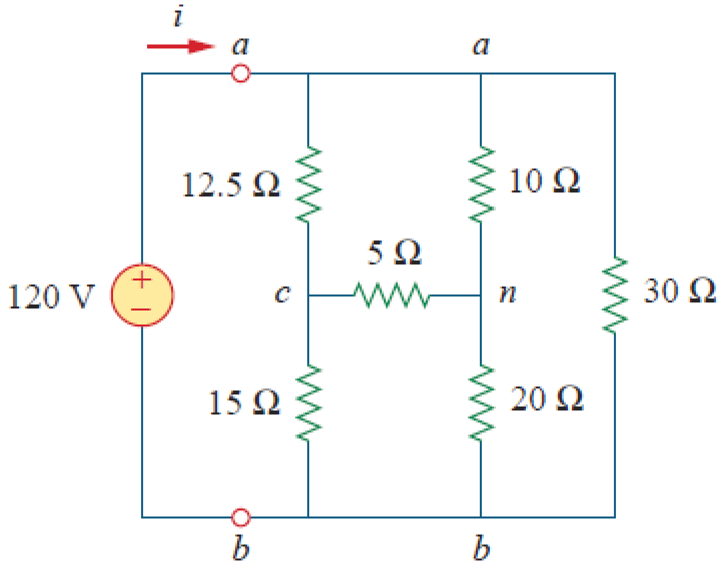
Each resistor in the Δ network is the sum of all possible products of Y resistors taken two at a time, divided by the opposite Y resistor.


a
R_c
b
25 Ω
10 Ω
15 Ω
R_b
R_a
c

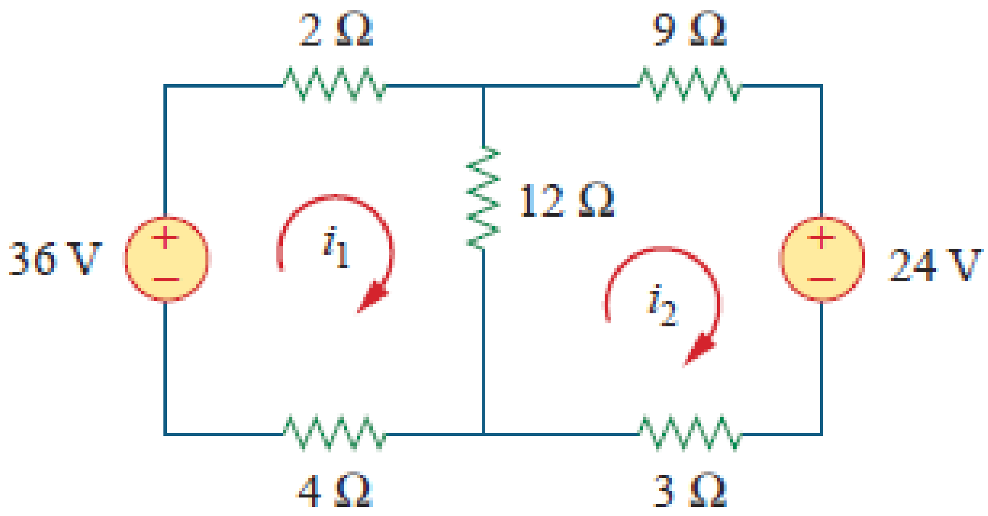

R_1
R_2
a
b
10 Ω
20 Ω
R_3
40 Ω
c

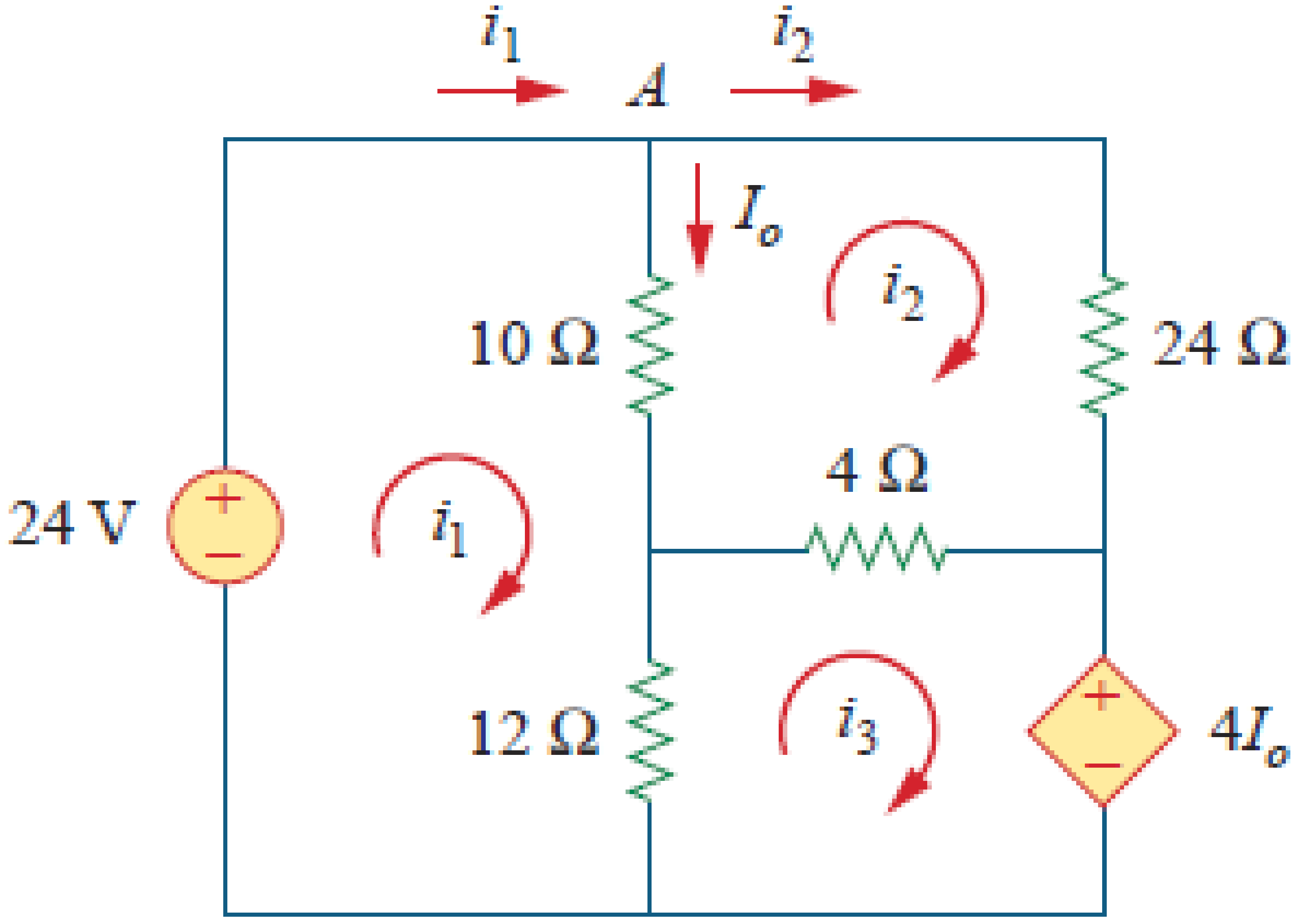


i
a
a
12.5 Ω
10 Ω
5 Ω
120 V
+
−
c
n
30 Ω
15 Ω
20 Ω
b
b

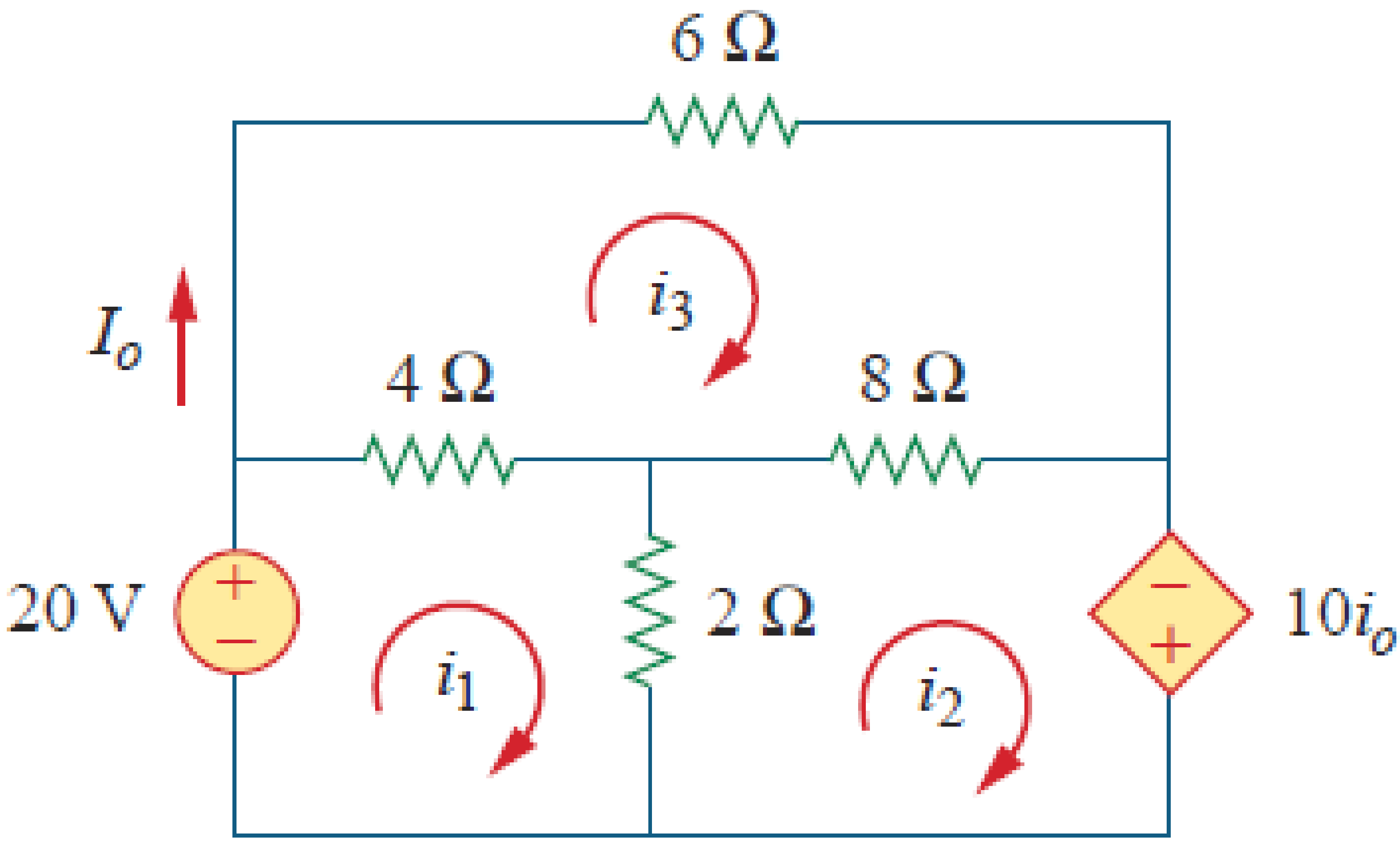

i
a
a
12.5 Ω
10 Ω
5 Ω
120 V
c
n
30 Ω
15 Ω
20 Ω
b
b

Mesh Analysis

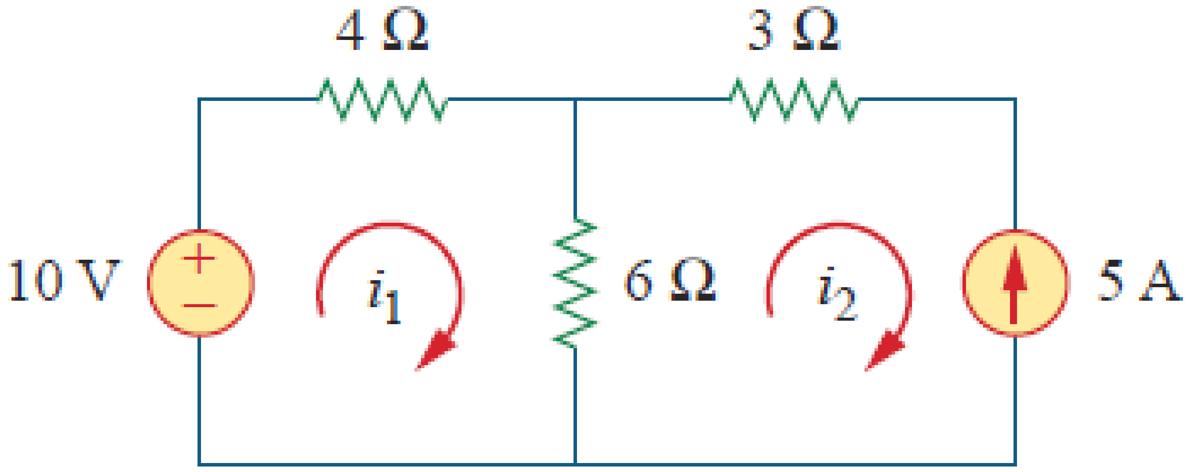




i_1
A
i_2
I_o
i_2
$10\ \Omega$
$24\ \Omega$
$4\ \Omega$
24 V
i_1
$12\ \Omega$
i_3
$4I_o$

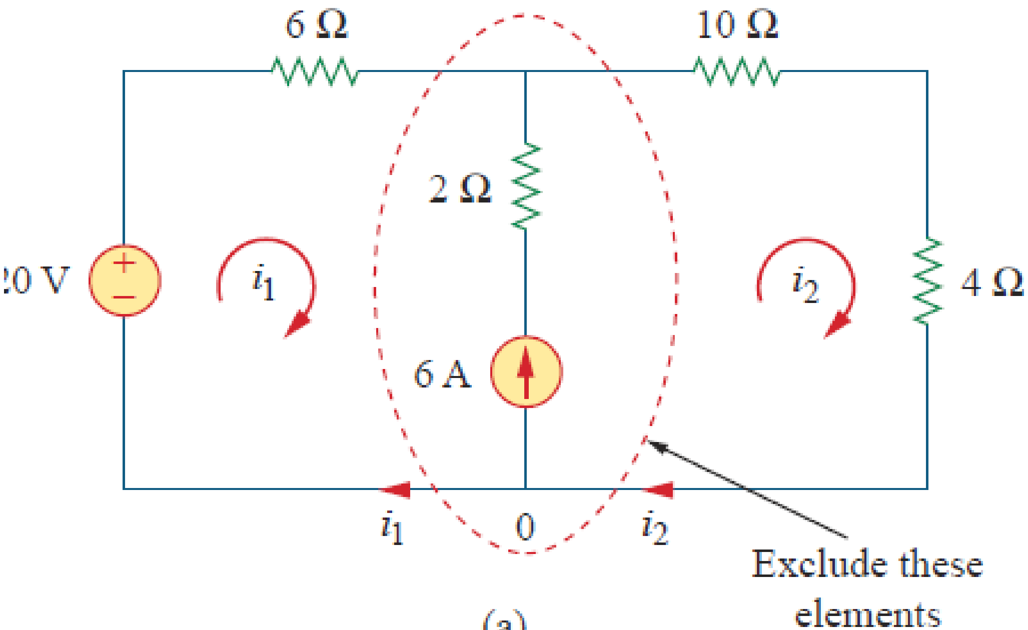


6 Ω
I_o
i_3
4 Ω
8 Ω
20 V
2 Ω
$10i_o$
i_1
i_2

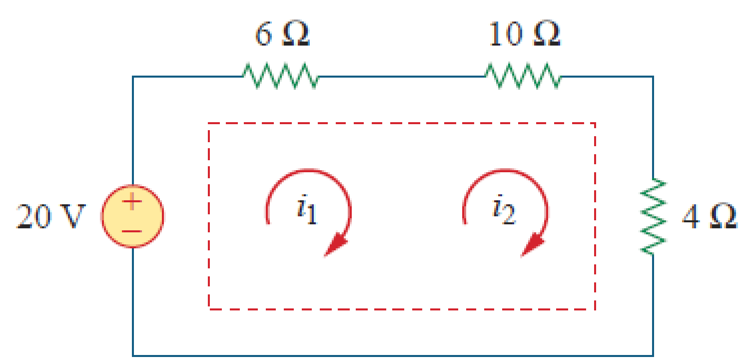

4 Ω
3 Ω
10 V
+
−
i_1
6 Ω
i_2
5 A

Super mesh

A **supermesh** results when two meshes have a (dependent or independent) current source in common.



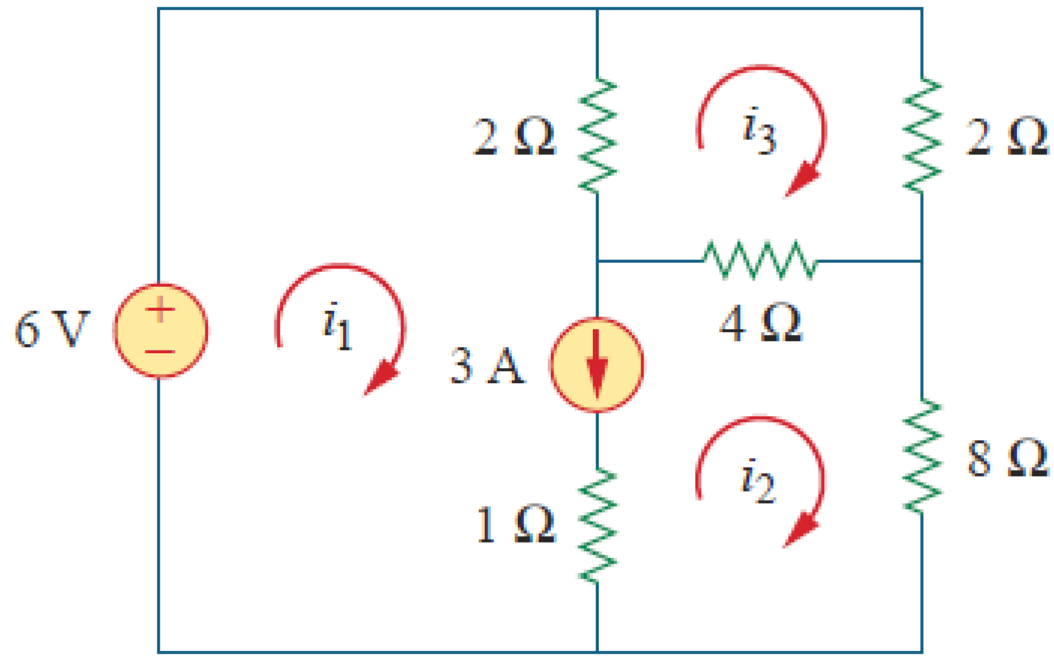
(a)

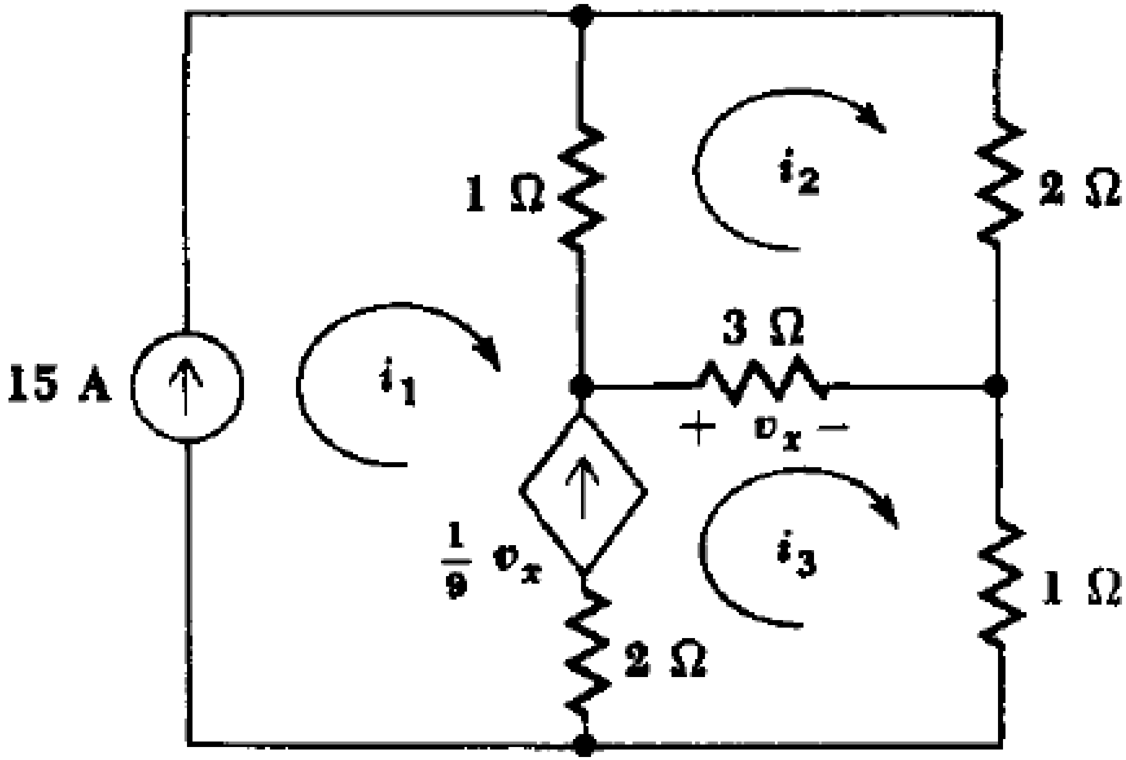


(b)

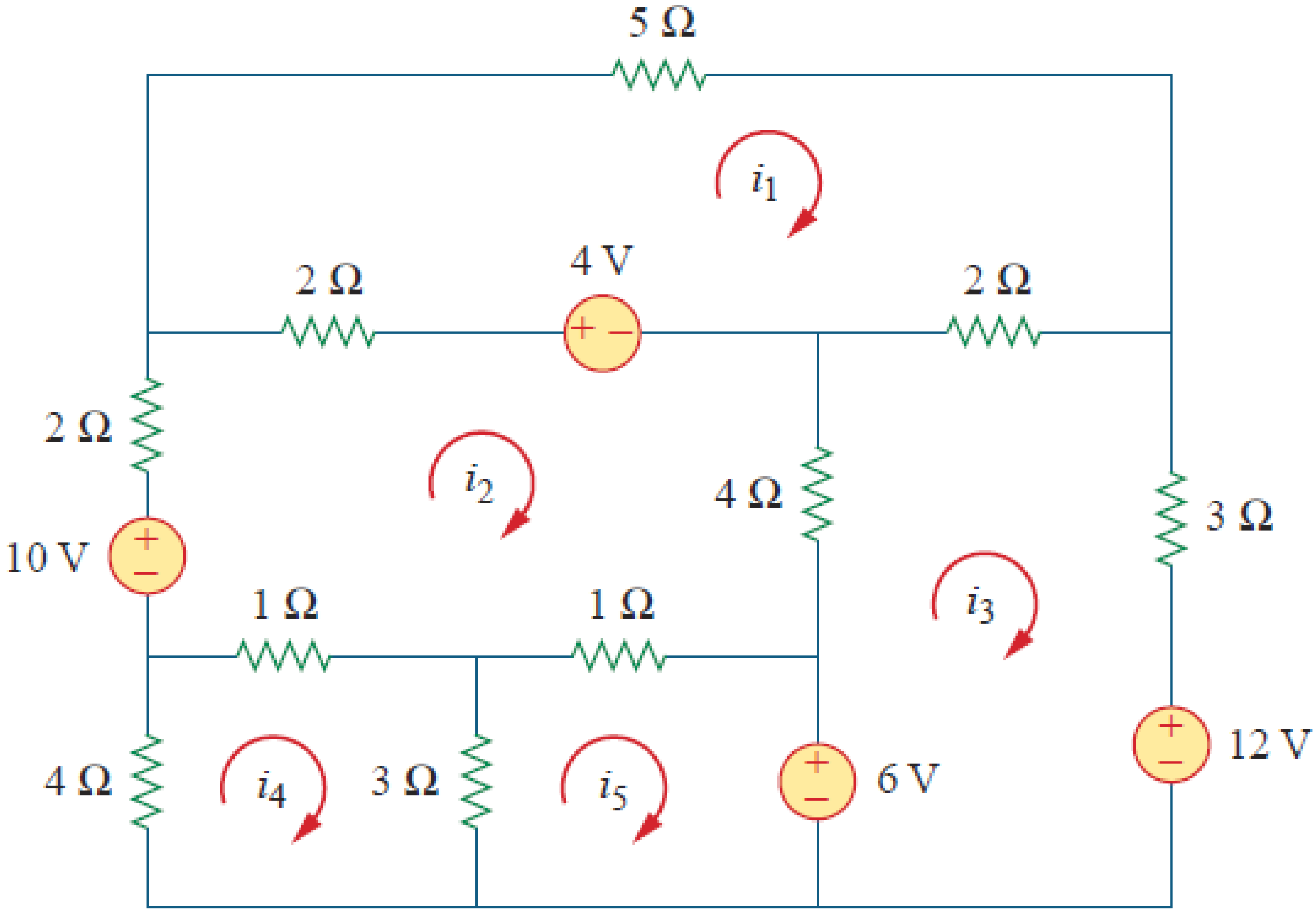
Note the following properties of a supermesh:

1. The current source in the supermesh provides the constraint equation necessary to solve for the mesh currents.
2. A supermesh has no current of its own.
3. A supermesh requires the application of both KVL and KCL.





1 Ω
2 Ω
i_2
i_1
3 Ω
15 A
+ v_x −
i_3
$\frac{1}{9}\ v_x$
1 Ω
2 Ω


5 Ω
i_1
2 Ω
4 V
2 Ω
2 Ω
i_2
4 Ω
3 Ω
10 V
i_3
1 Ω
1 Ω
4 Ω
i_4
3 Ω
i_5
6 V
12 V