BASIC ELECTRONIC CIRCUITS

Circuit theory concepts

Contents

- Basic quantities: Charge, Current, voltage and Power.
- Ohm's Law: Resistance and resistivity
- Kirchhoff's laws
- Resistors in series and parallel

Charge (C)

- Charge conservation: "Neither create nor destroy"
- Two type: +ve (proton) and –ve (electron)
- Electron flow is relevant
- Flow of +ve charge is important in understanding internal operation (Eg: battery, diode, and transistor)
- A single electron has a charge of -1.602×10^{-19} C

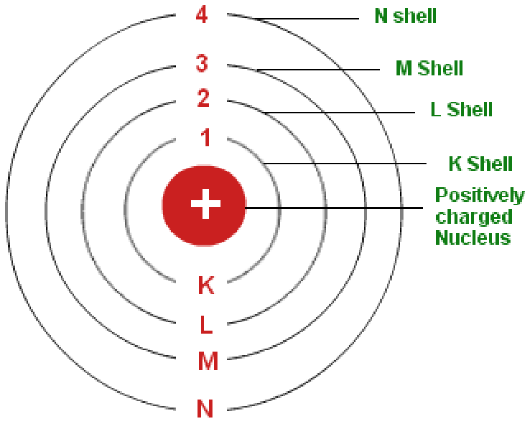
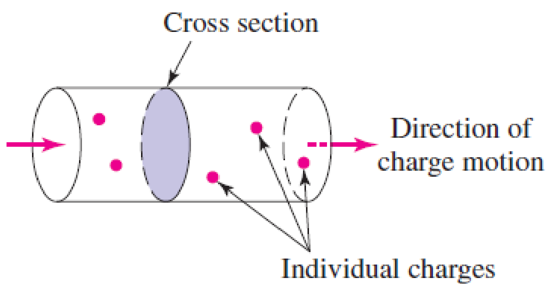


Fig. Bohr's Atomic Model

Current



- Flow of charge leads to "CURRENT", in moving charge from one place to another, we also transfer energy from one point to another.
- Ex: electrical power transmission.
- Further, it is possible to vary the rate at which the charge is transferred in order to communicate or transfer information (Ex: communication systems)
- Measure of rate at which charge is moving past a given reference point in a specified direction.

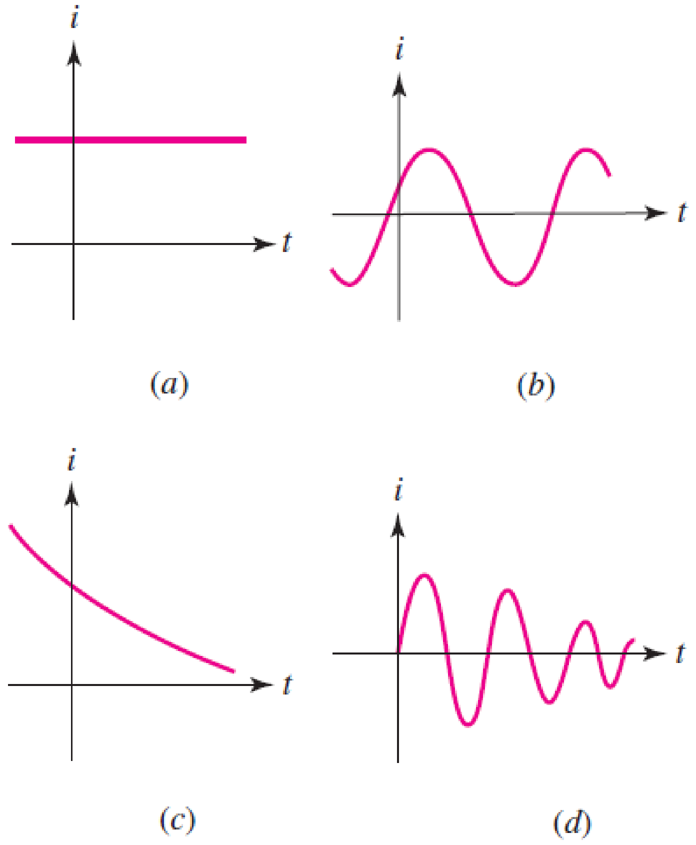


Fig. Several types of current

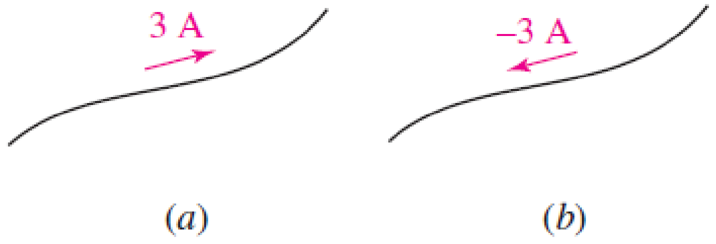
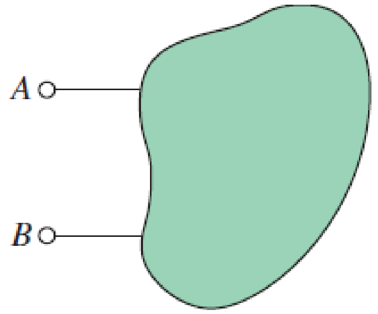


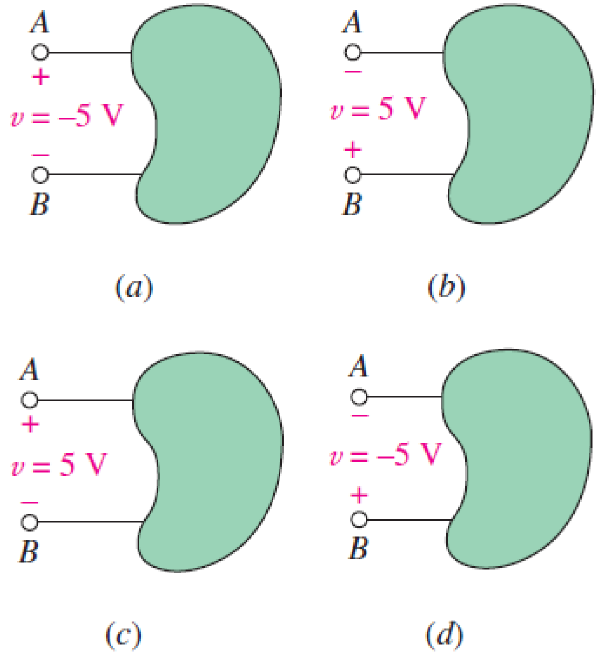
Fig. Representation of current

Voltage

- A DC current is sent into A and back out of B, Hence an electric voltage exists between the two terminals



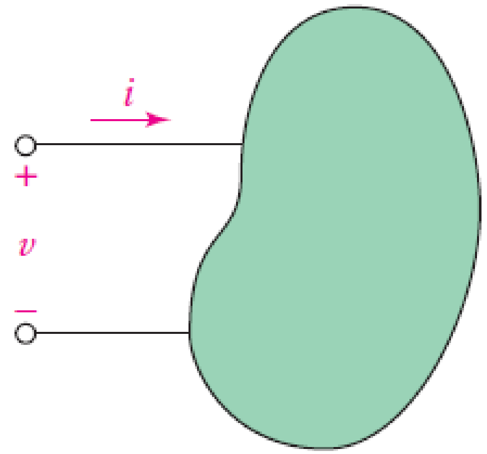
An example of a two terminal circuit element.



Terminal voltage representation.

Power

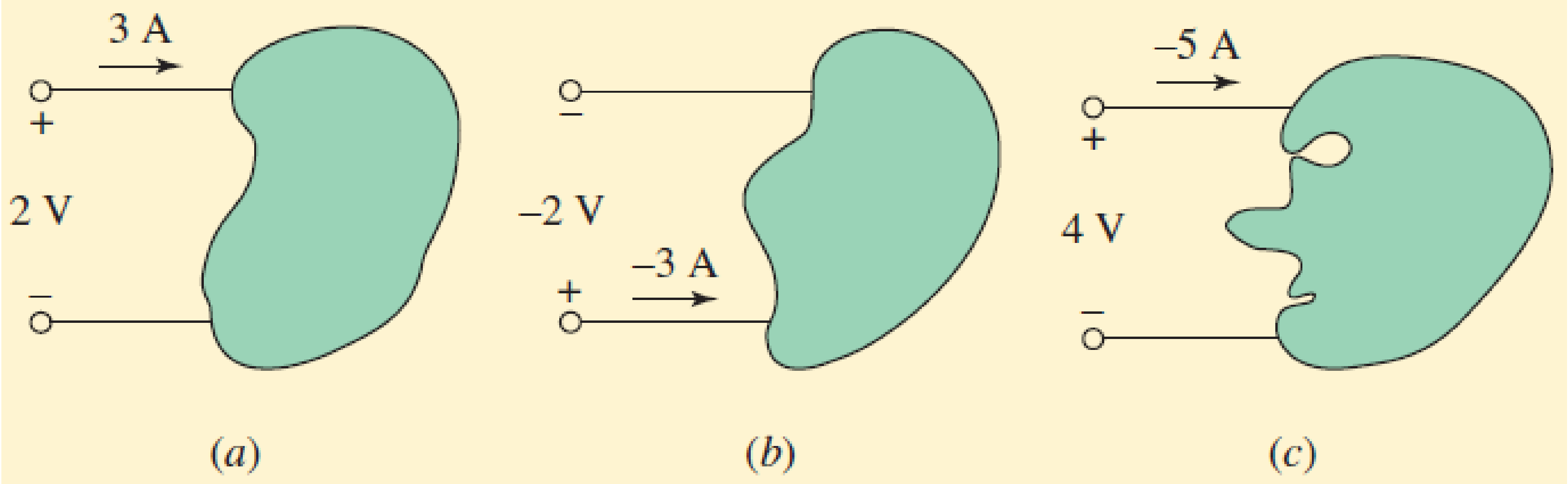
- Rate at which the electrical energy is transferred.
- P = VI
- Units: Watt, Joule/sec
- Sign conventions: +10 J/s, -10 J/s



The power absorbed by the element is given by the product of P = VI.

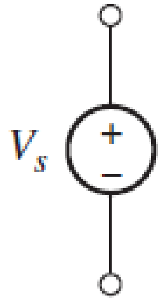
Power

- Compute the power absorbed:

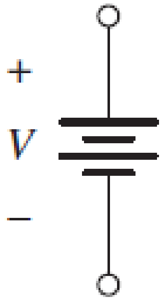


Independent Sources

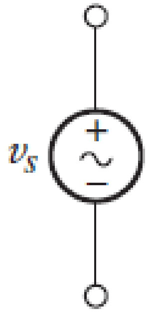
- Voltage source



Dc voltage

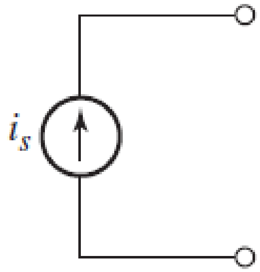


Battery

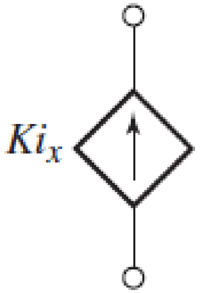


AC voltage

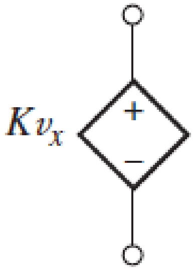
- Current Source



Dependent sources

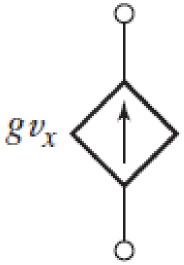


Current controlled current source

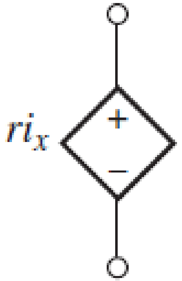


Voltage controlled voltage source

K is a dimensionless scaling factor.



Voltage controlled current source

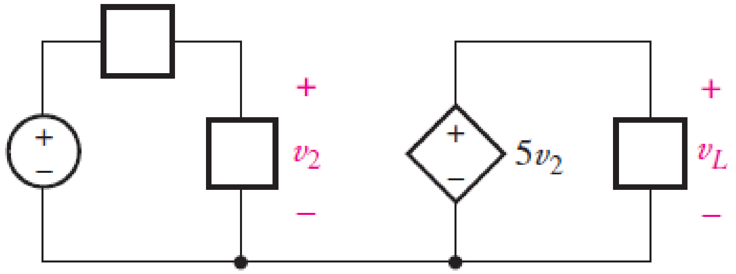


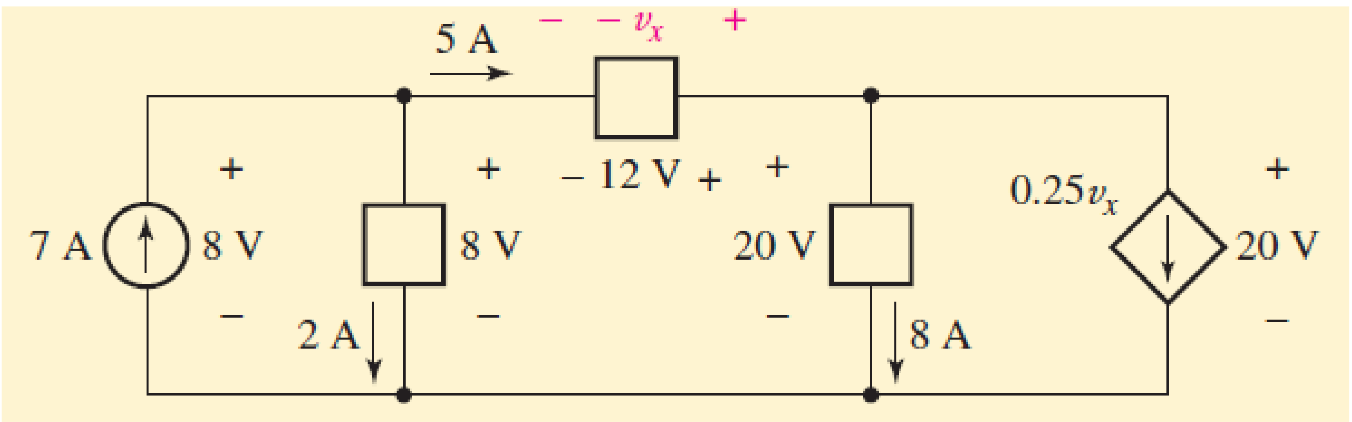
Current controlled voltage source

g, r are the scaling factor with units A/V and V/A respectively.

Examples:

- If v_2 = 3 V, determine v_L.
- Ans: V_L = 15 V.
- Find the power absorbed by each element





Ans: (left to right) −56 W; 16 W; −60 W; 160 W; −60 W.

Ohm's Law

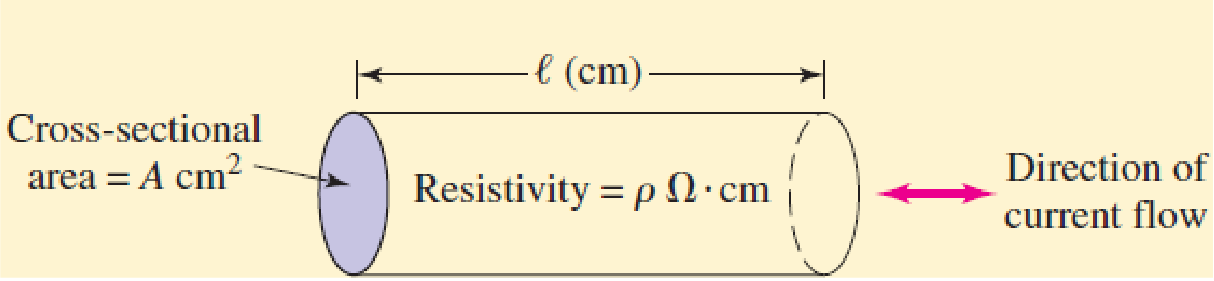
- Statement: The voltage across "conducting" material is directly proportional to the current flowing through the material
- $V = IR$, R – constant of proportionality, unit is ohm.
- Power absorption, $P = VI = I^2R = V^2/R$

Aluminium bar

Wooden bar

Resistance and Resistivity

- Resistance = Resistivity * length of the bar/Cross-sectional area of the bar
- $R = \rho l/A$
- Conductivity=1/resistivity; $\sigma = 1/\rho$



Dependency on:

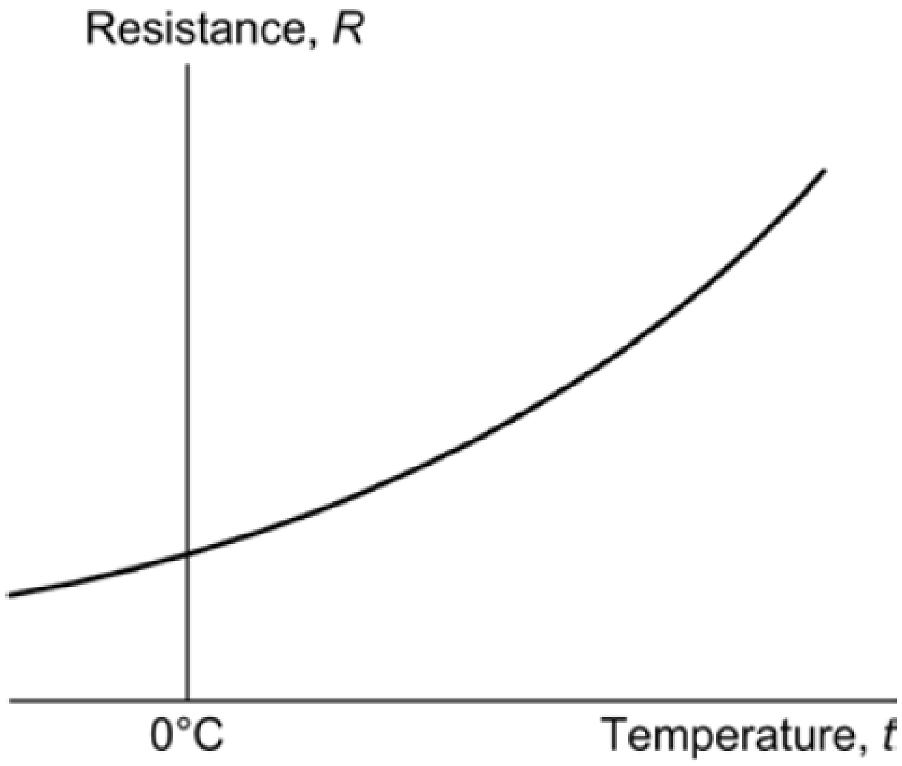
- Temperature: with increase in temp. resistivity increases.

$$R_t = R_0(1 + \alpha\, t)$$

- α is called temperature coefficient (/°C)

- Ex: A resistor has a temperature coefficient of 0.001 /°C. if the resistor has a resistance of 1.5 KΩ at 0°C, determine the resistance at 80°C?

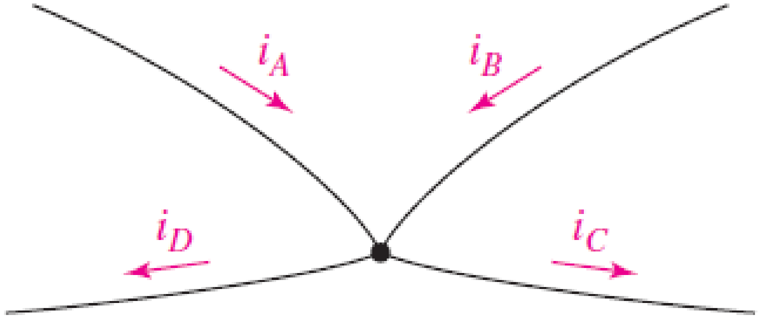
- Ans: 1.62 kΩ



Kirchhoff's Laws: KCL

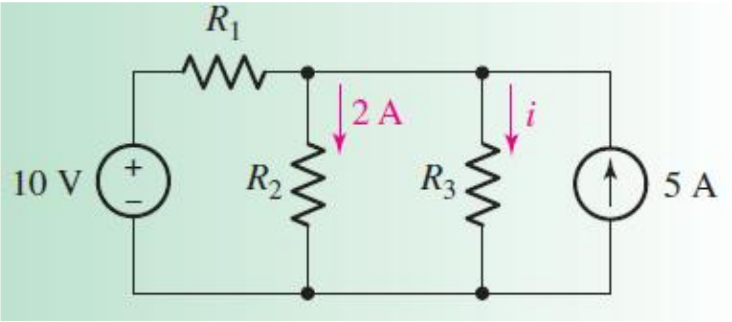
$$\sum_{n=1}^{N} i_n = 0$$

- Algebraic sum of currents entering the node is zero.



$$i_A + i_B + (-i_C) + (-i_D) = 0$$

- Ex 1: if the voltage source produces a current 3A, determine i?

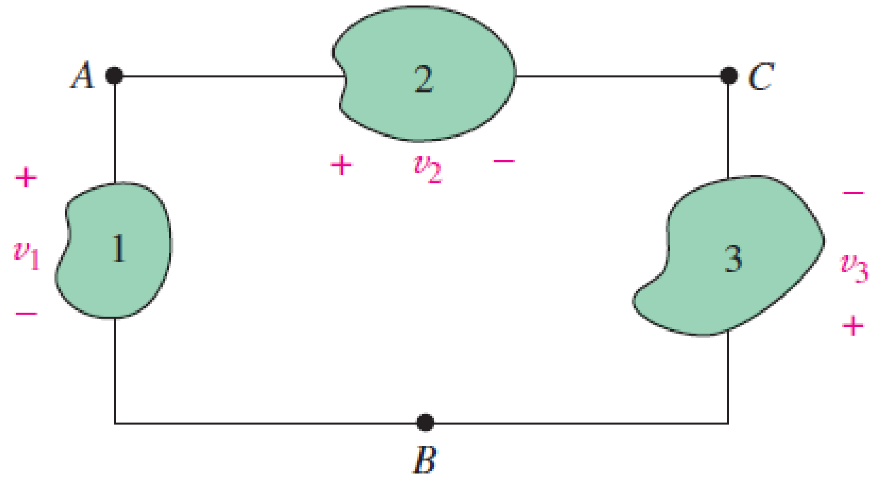


- Ans: i = 6 A.

KVL

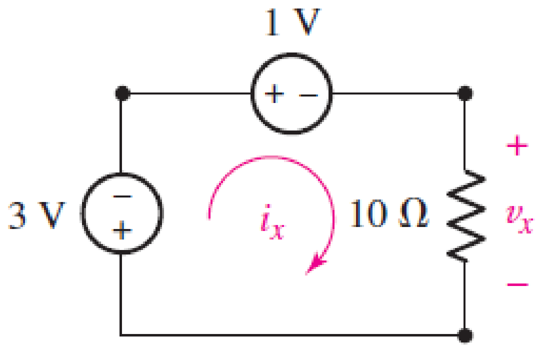
- The algebraic sum of voltages around any closed path is zero.

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



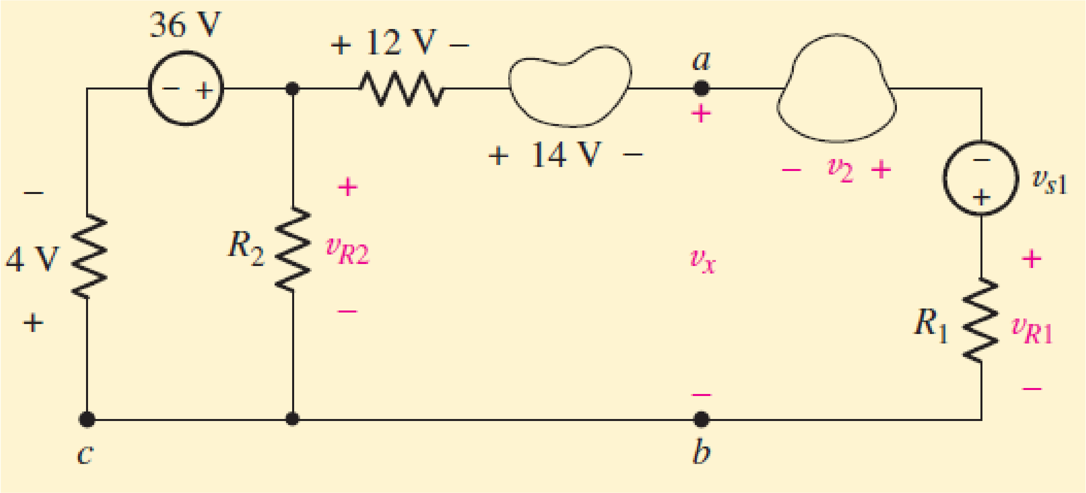
$$-v_1 + v_2 - v_3 = 0$$

- Ex 2: Determine v_x and i_x
- Ans: v_x = -4 V and i_x = -400 mV.



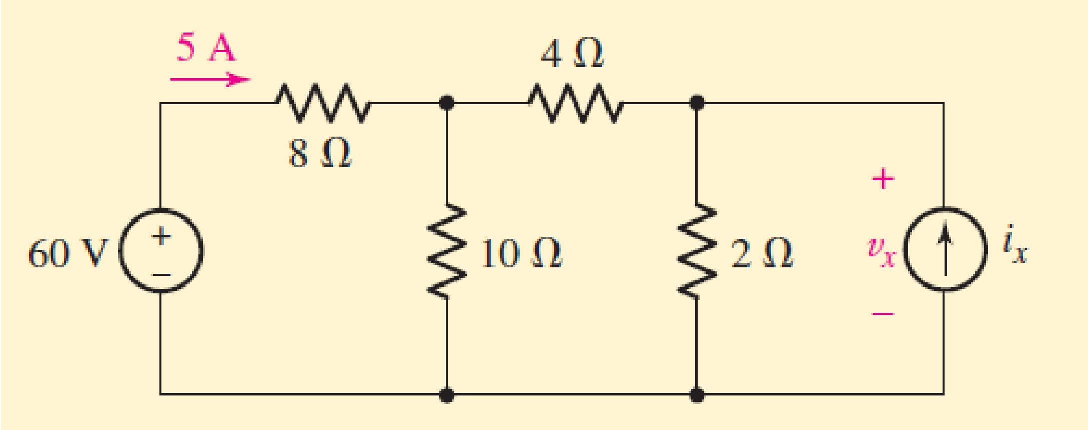
Example:

- Determine: v_{r2} and v_x .



- Ans: v_{r2} = 32 V and v_x = 6 V.

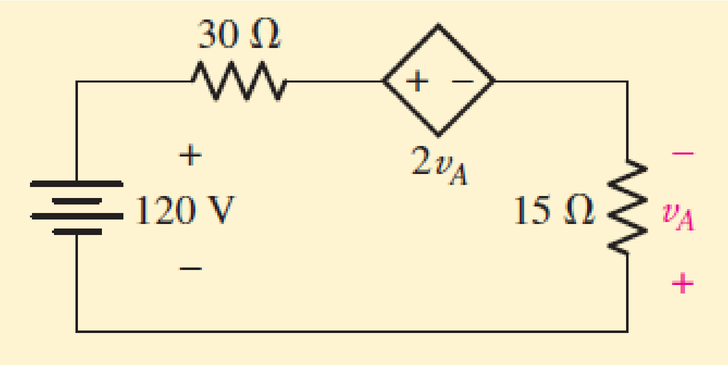
- Determine: v_x.



- Ans: v_x = 8 V.

Single loop and single node circuits

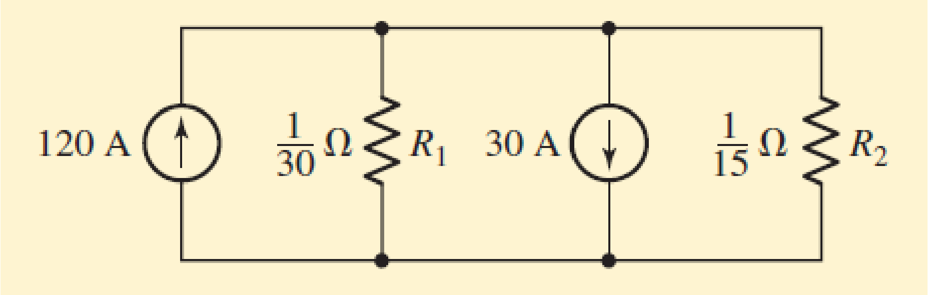
- Compute the power absorbed in each element.



- Ans: i = 8 A

$$
\begin{aligned}
p_{120\text{V}} &= (120)(-8) = -960 \text{ W}\\
p_{30\Omega} &= (8)^2(30) \quad = 1920 \text{ W}\\
p_{\text{dep}} &= (2v_A)(8) \quad = 2[(-15)(8)](8)\\
&\qquad\qquad\quad = -1920 \text{ W}\\
p_{15\Omega} &= (8)^2(15) \quad = 960 \text{ W}
\end{aligned}
$$

- Find the current, voltage, and power associated with each element.

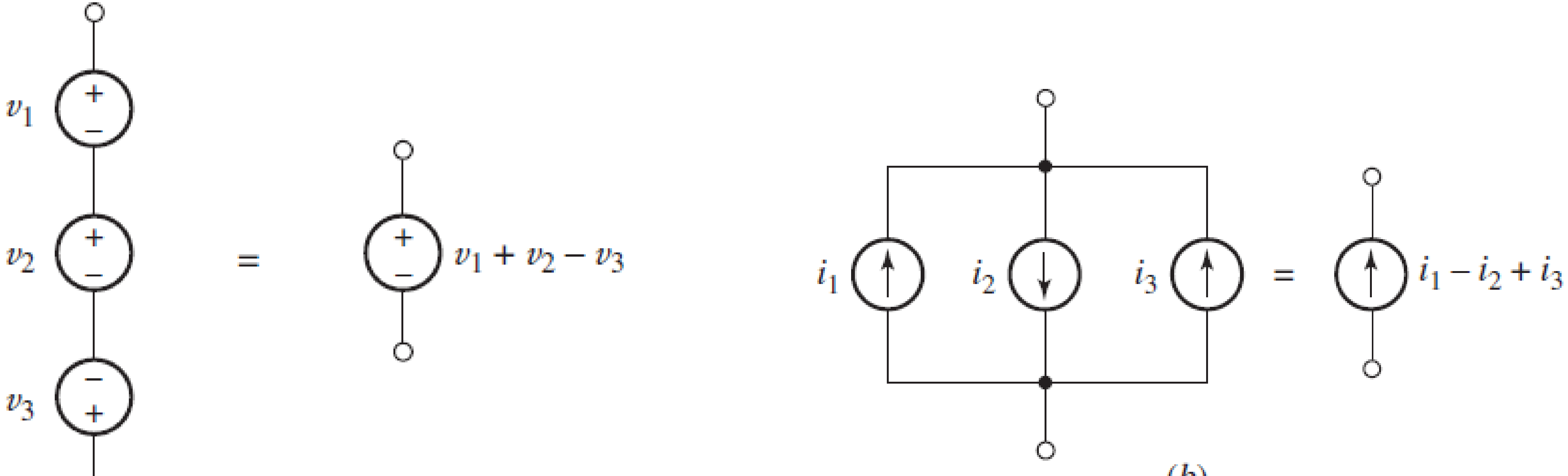


- Ans: v = 2 V;

$$p_{R1} = 30(2)^2 = 120 \text{ W} \quad \text{and} \quad p_{R2} = 15(2)^2 = 60 \text{ W}$$

$$p_{120\text{A}} = 120(-2) = -240 \text{ W} \quad \text{and} \quad p_{30\text{A}} = 30(2) = 60 \text{ W}$$

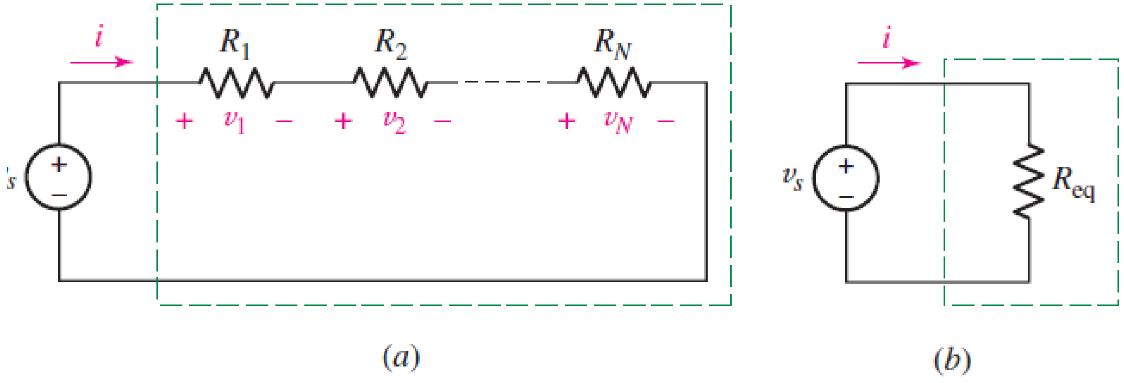
Series and parallel connected sources



(a)

(b)

Resistors in series



$$v_s = R_1 i + R_2 i + \cdots + R_N i = (R_1 + R_2 + \cdots + R_N)i$$

$$v_s = R_{eq} i$$

$$\boxed{R_{eq} = R_1 + R_2 + \cdots + R_N}$$

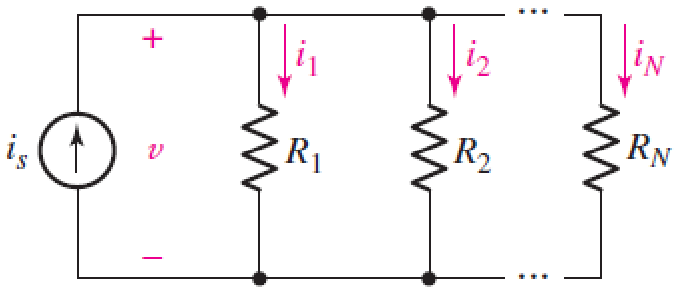
Resistors in parallel

$$i_s = i_1 + i_2 + \cdots + i_N$$

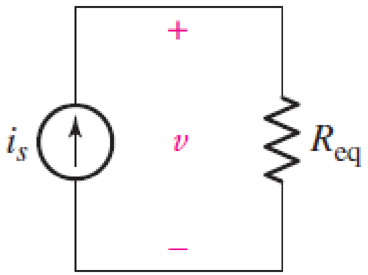
$$i_s = \frac{v}{R_1} + \frac{v}{R_2} + \cdots + \frac{v}{R_N}$$

$$= \frac{v}{R_{eq}}$$

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



(a)



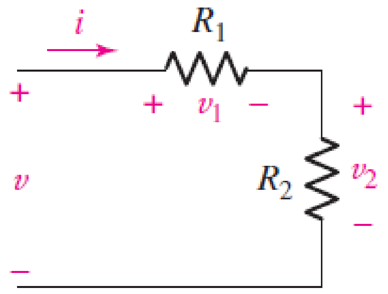
(b)

Voltage division

$$v = v_1 + v_2 = iR_1 + iR_2 = i(R_1 + R_2)$$

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

$$\boxed{v_k = \frac{R_k}{R_1 + R_2 + \cdots + R_N} v}$$



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

Current division

$$i_2 = \frac{v}{R_2} = \frac{i(R_1 \| R_2)}{R_2} = \frac{i}{R_2} \frac{R_1 R_2}{R_1 + R_2}$$

$$\boxed{i_2 = i \frac{R_1}{R_1 + R_2}} \qquad \boxed{i_1 = i \frac{R_2}{R_1 + R_2}} \qquad \boxed{i_k = i \frac{\frac{1}{R_k}}{\frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_N}}}$$