BASIC ELECTRONIC CIRCUITS

Review of Basic Concepts

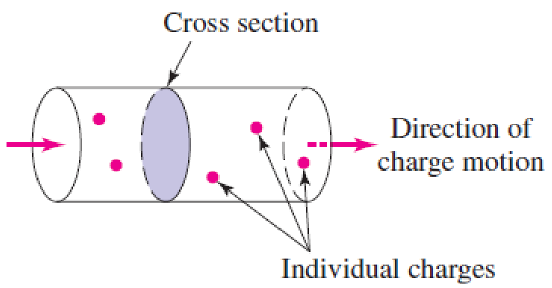
Contents

- 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

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.

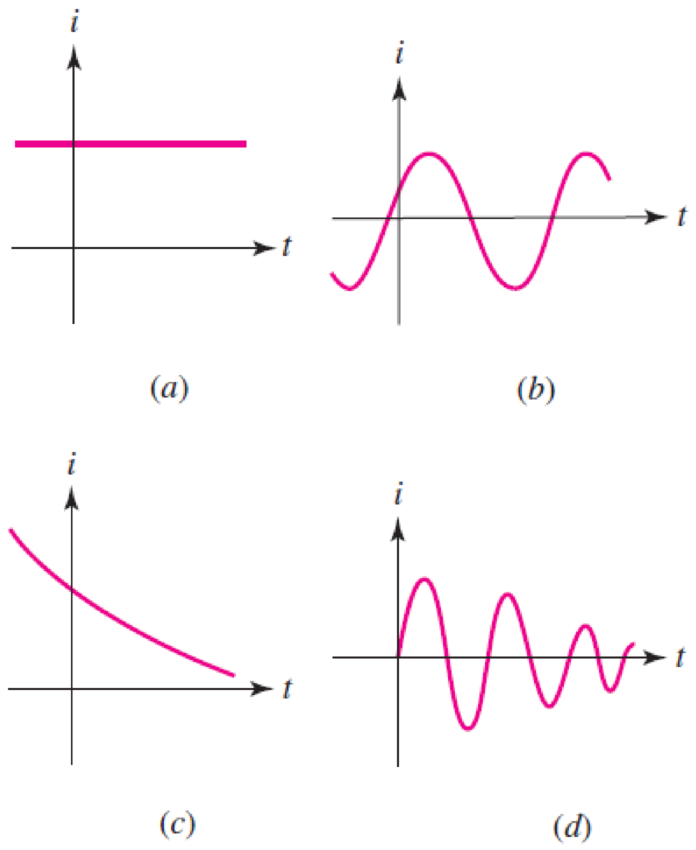


Fig. Several types of current

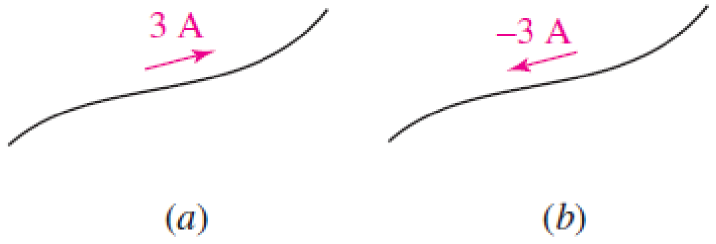
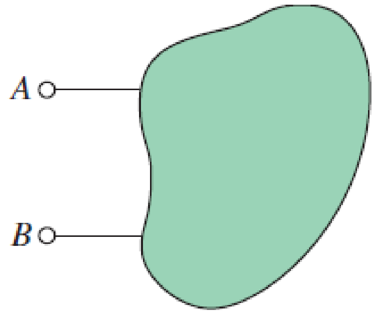


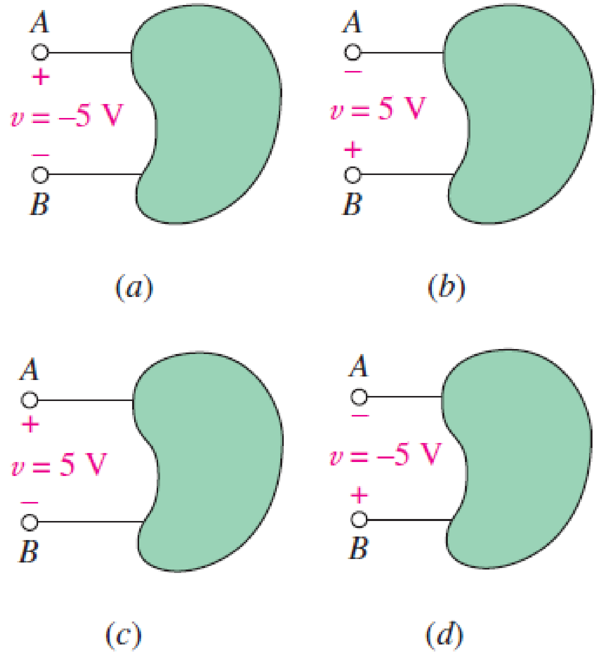
Fig. Representation of current

Voltage

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



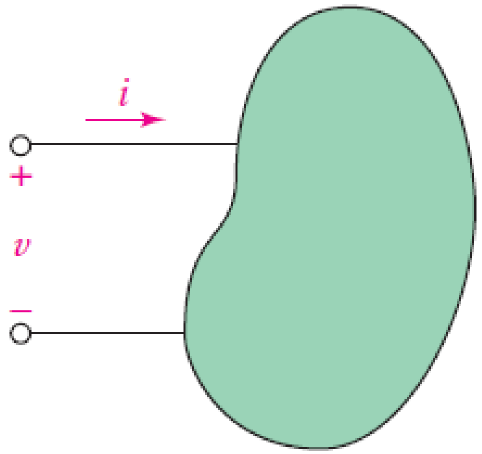
An example of a two terminal circuit element.



Terminal voltage representation.

Power

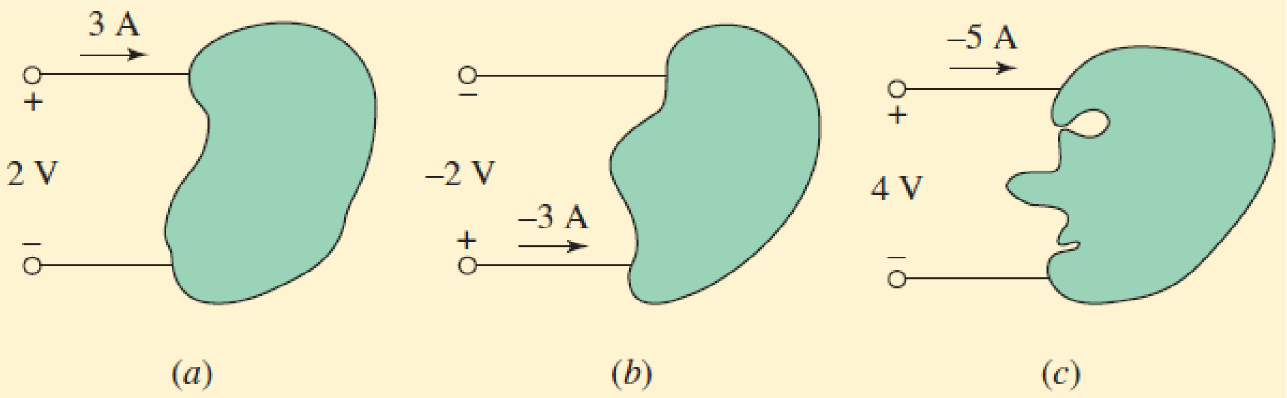
- Rate at which the electrical energy is transferred.
- P = VI
- Units: Joule/sec
- Sign conventions: +10 J/s, -10 J/s



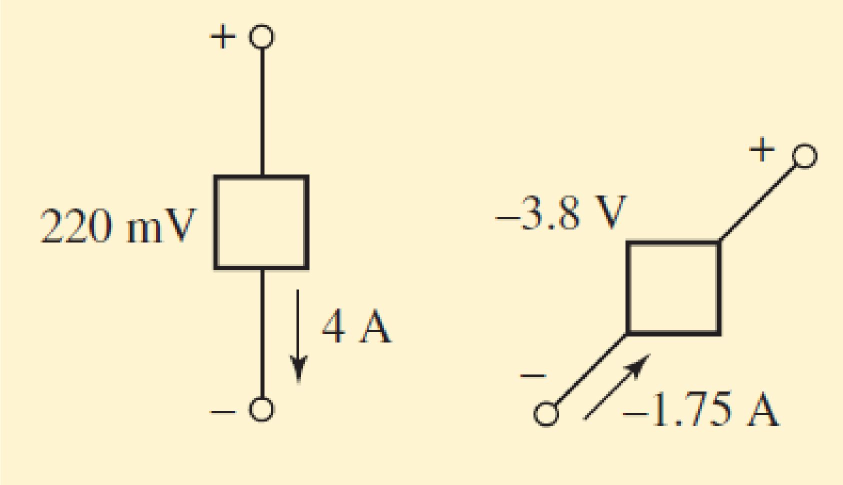
The power absorbed by the element is given by the product of P = VI, passive sign convention.

Power

- Compute the power absorbed:



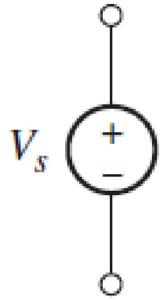
- Ans: 6 W, 6 W, and -20 W



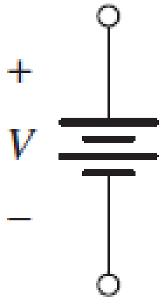
- 880 mW, -6.65 W.

Independent Sources

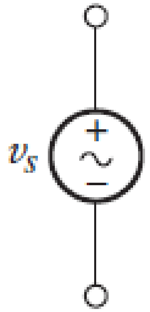
- Voltage source



Dc voltage

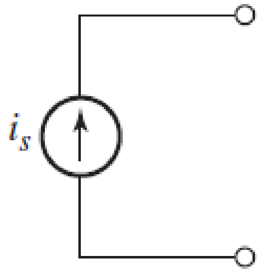


Battery

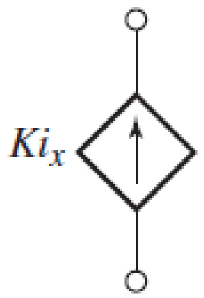


AC voltage

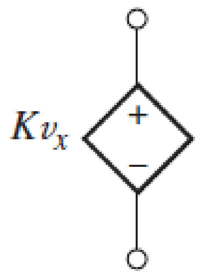
- Current Source



Dependent sources

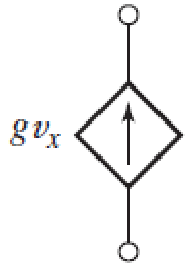


Current controlled current source

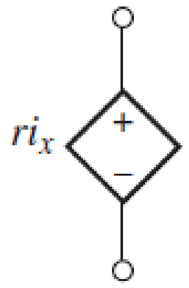


Voltage controlled voltage source

K is a dimensionless scaling factor.



Voltage controlled current source

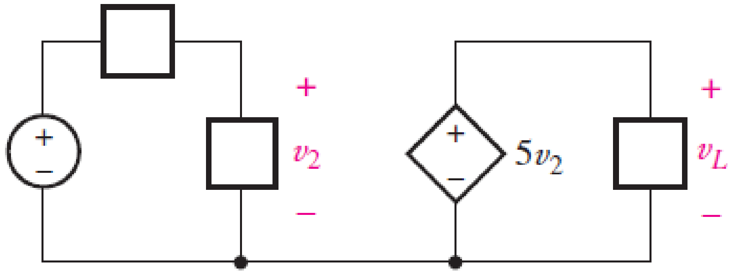


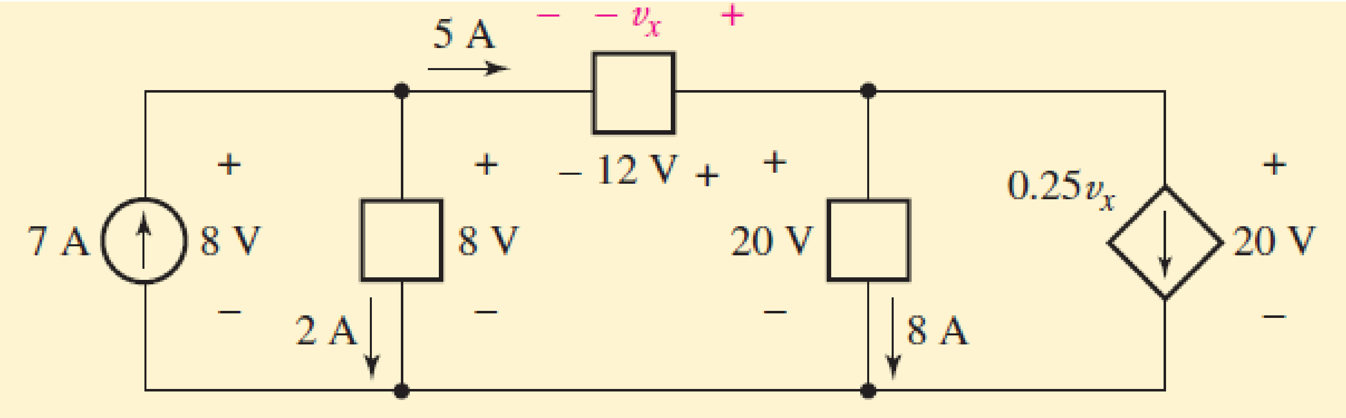
Current controlled voltage source

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

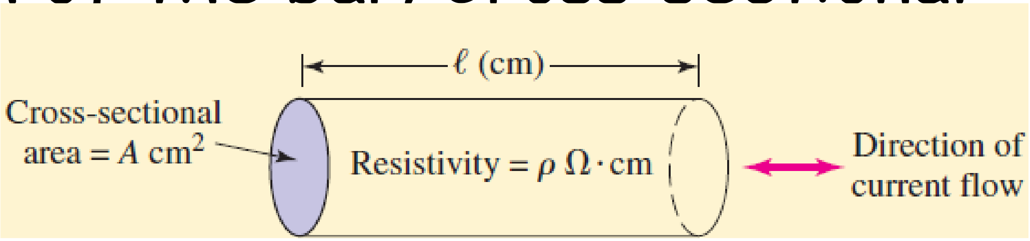
- Statement: The voltage across "conducting" material is directly proportional to the current flowing through the material
- $V = IR$, R - constant of proportionality, unit is ohm.
- Power absorption, $P = VI = I^2R = V^2/R$

Aluminium bar

Wooden bar

Resistance and Resistivity

- Resistance = Resistivity * length of the bar/Cross-sectional area of the bar



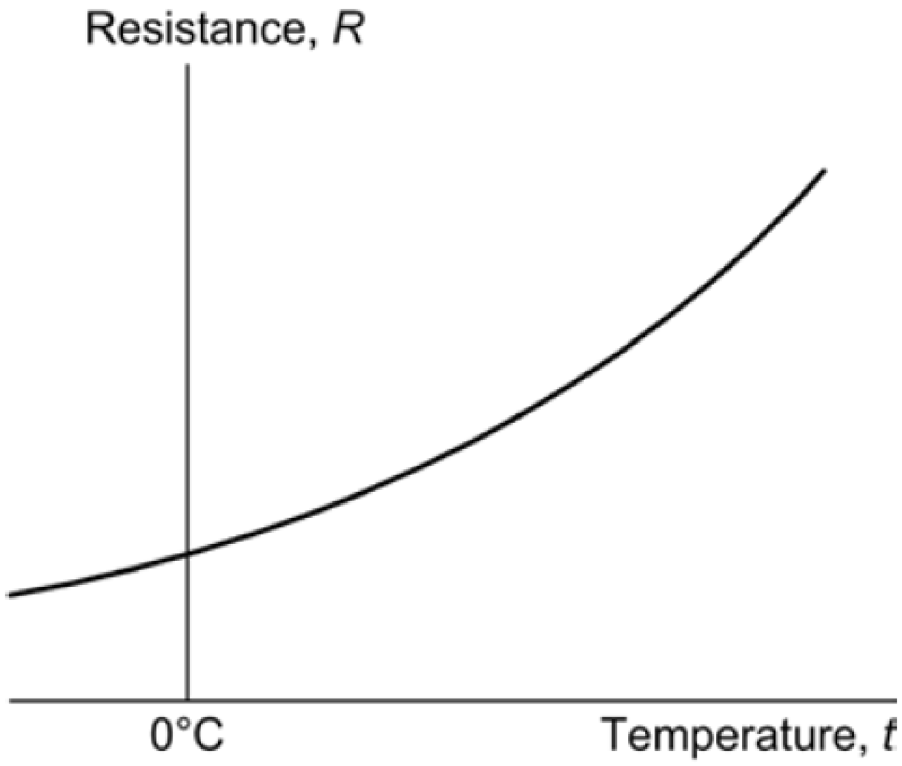
- R = ρl/A
- Conductivity=1/resistivity; σ = 1/ρ

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



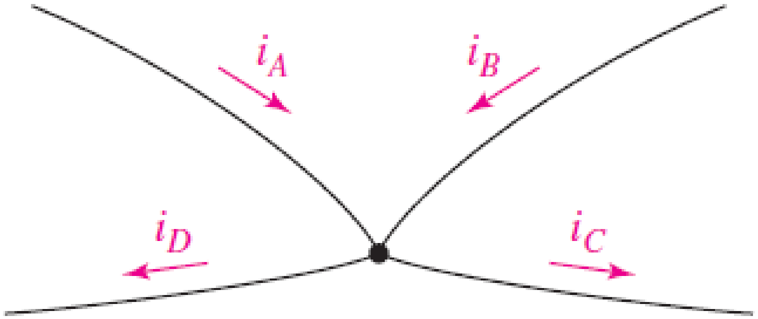
Conductance

- $G = i/v = 1/R$
- Units: mho, S
- Power $p = vi = v^2G = i^2/G$
- Ex: A dc power link is to be made between two islands separated by a distance of 24 miles. The operating voltage is 500 kV and the system capacity is 600 MW. Calculate the maximum dc current flow, and estimate the resistivity of the cable, assuming a diameter of 2.5 cm and a solid wire.
- Ans: I = 1200 A, R = 417 ohms, resistivity = 520 μΩ.cm.

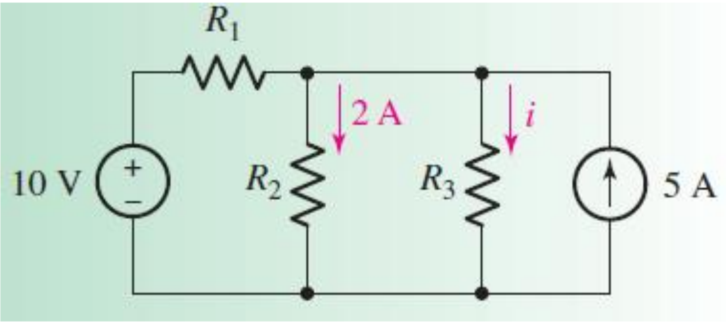
Kirchhoff's Laws: KCL

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

- Algebraic sum of currents entering the node is zero.
- "A node is not a circuit element", it cannot store, dissipate, or generate charge.
- Sum of the currents (iA + iB) going in must equal to the sum of currents (iC + iD) going out.
- Ex 1: if the voltage source produces a current 3A, determine i?
- Ans: i = 6 A.



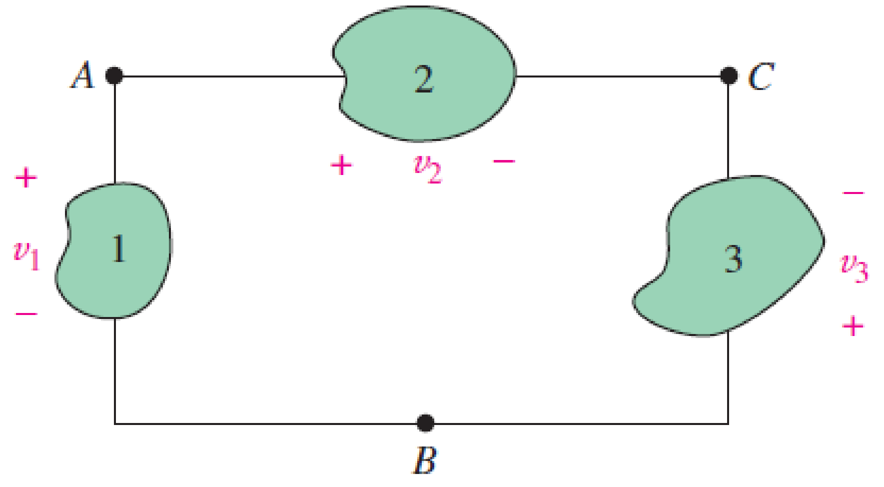
$$i_A + i_B + (-i_C) + (-i_D) = 0$$



KVL

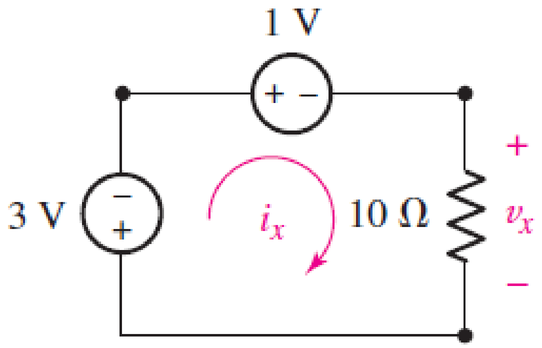
- The algebraic sum of voltages around any closed path is zero.

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



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

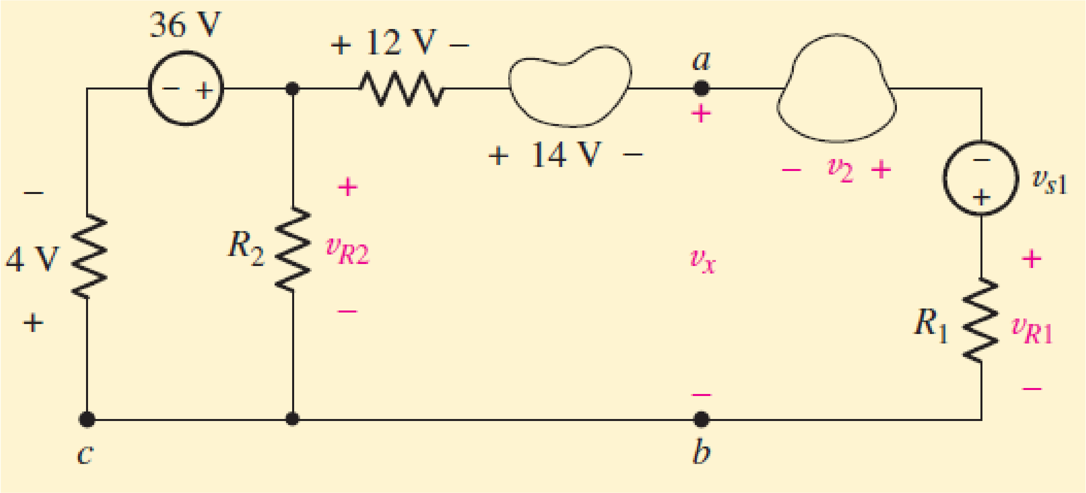
- Ex 2: Determine v_x and i_x
- Ans: v_x = -4 V and i_x = -400 mV.



Example:

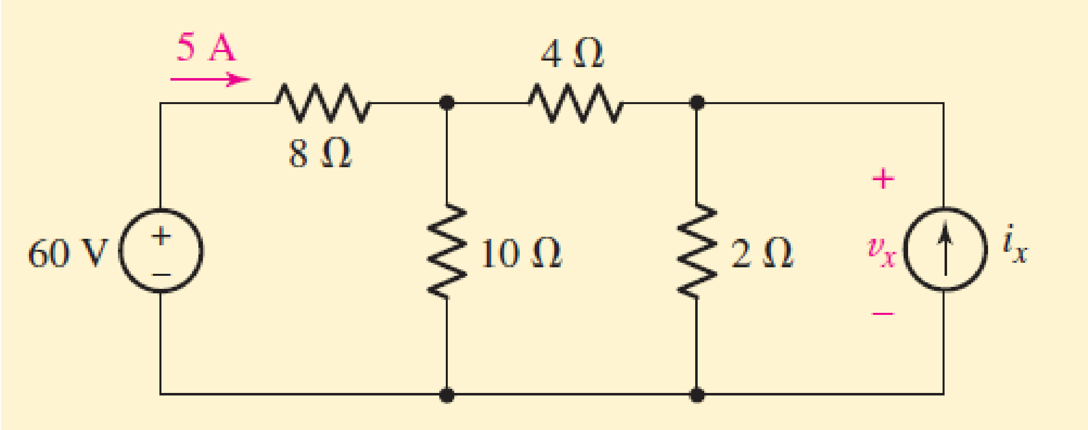
- Determine: v_{r2} and v_x .

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



- Determine: v_x.

- Ans: v_x = 8 V.

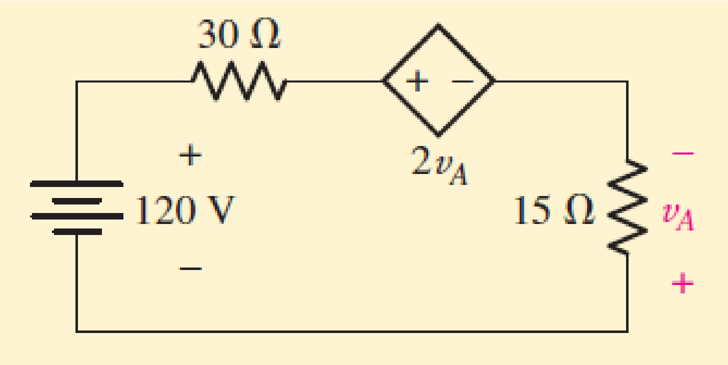


Single loop and single node circuits

- Compute the power absorbed in each element.

- Ans: i = 8 A

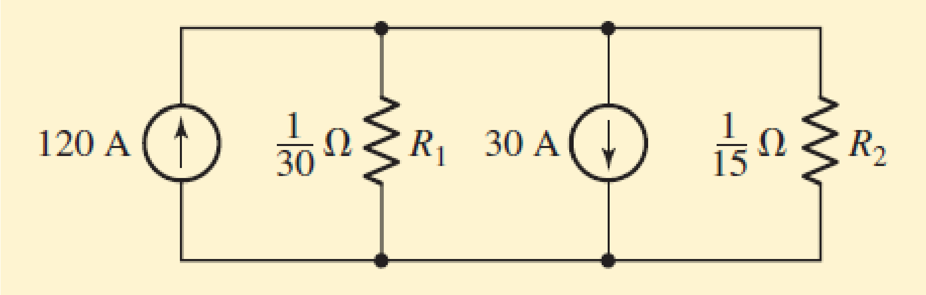
$$
\begin{aligned}
p_{120\text{V}} &= (120)(-8) &&= -960\text{ W} \\
p_{30\Omega} &= (8)^2(30) &&= 1920\text{ W} \\
p_{\text{dep}} &= (2v_A)(8) &&= 2[(-15)(8)](8) \\
& &&= -1920\text{ W} \\
p_{15\Omega} &= (8)^2(15) &&= 960\text{ W}
\end{aligned}
$$



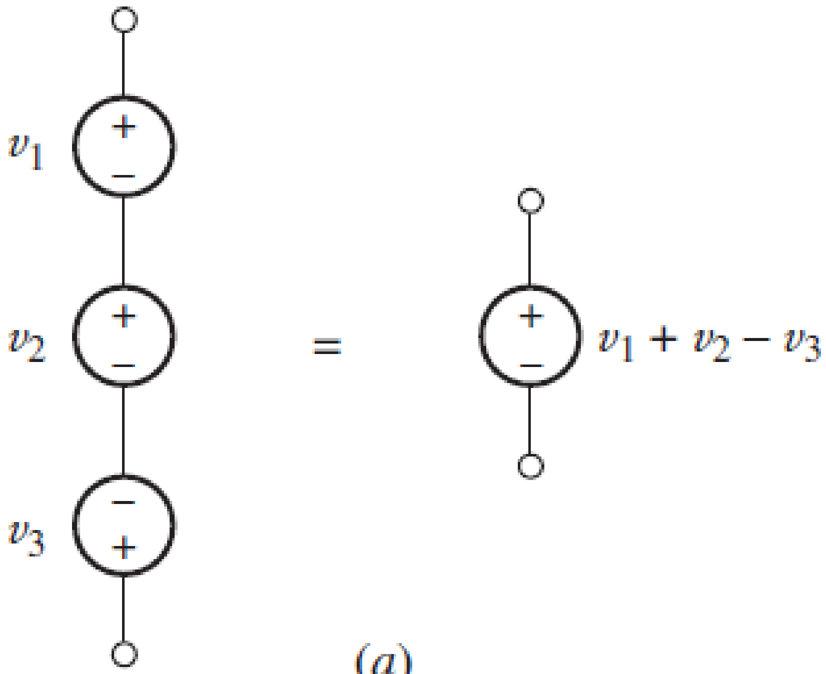
- Find the current, voltage, and power associated with each element.
- Ans: v = 2 V;

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

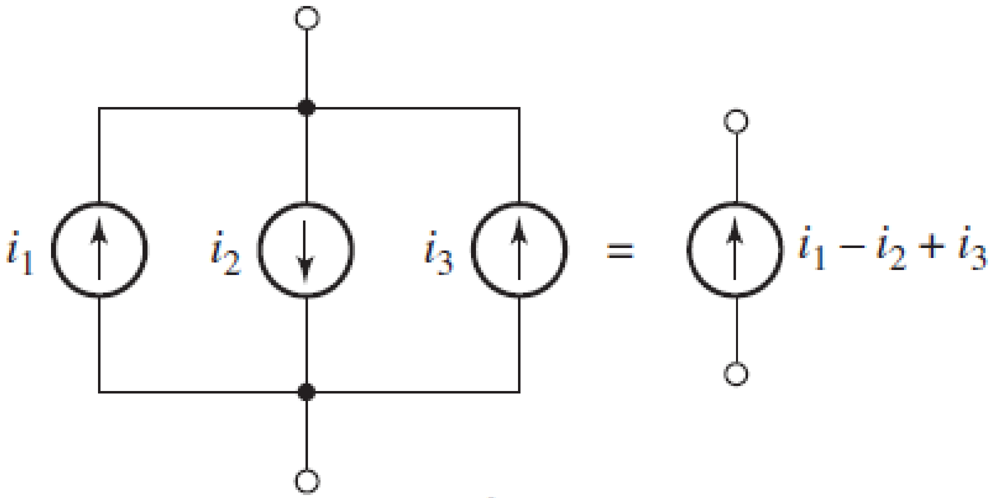
$$p_{120\text{A}} = 120(-2) = -240\text{ W} \quad \text{and} \quad p_{30\text{A}} = 30(2) = 60\text{ W}$$



Series and parallel connected sources

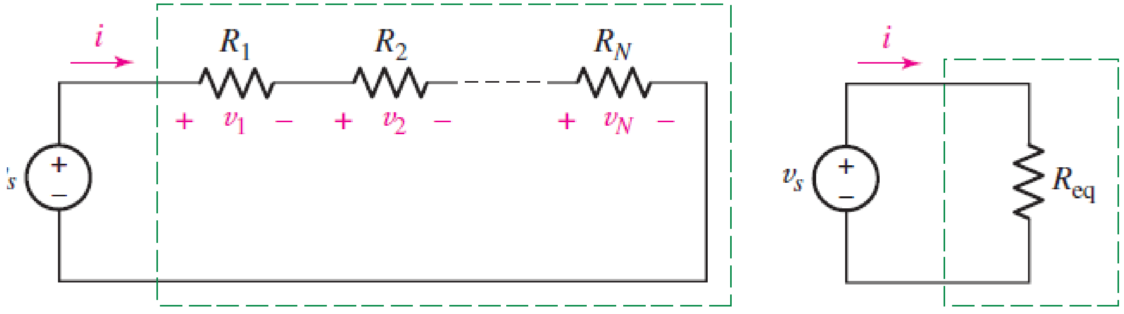


(a)



(b)

Resistors in series



(a) (b)

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

$$v_s = R_{\text{eq}} i$$

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

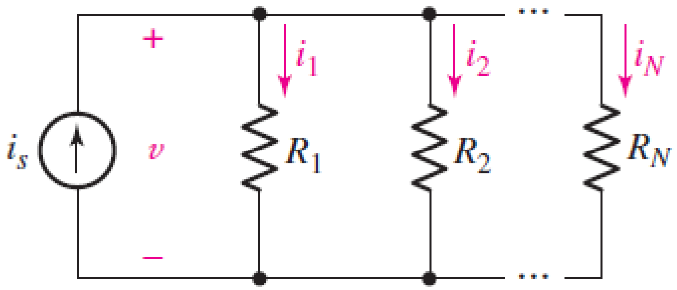
Resistors in parallel

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

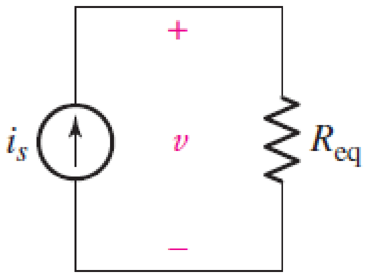
$$i_s = \frac{v}{R_1} + \frac{v}{R_2} + \cdots + \frac{v}{R_N}$$

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

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



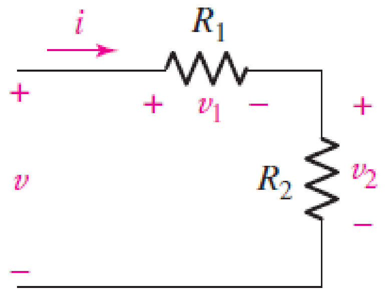
(*a*)



(*b*)

Voltage division

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



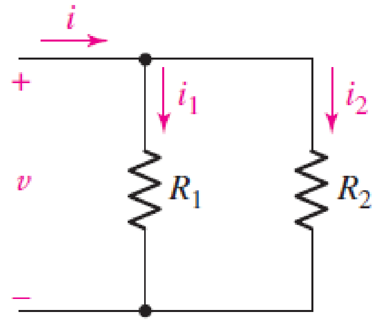
$$v_2 = \frac{R_2}{R_1 + R_2} v \qquad v_1 = \frac{R_1}{R_1 + R_2} v$$

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

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

Current division

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

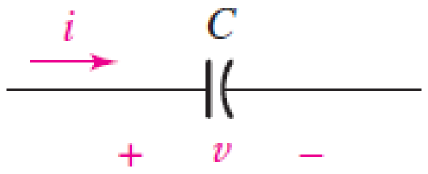


$$\boxed{i_2 = i \frac{R_1}{R_1 + R_2}} \qquad \boxed{i_1 = i \frac{R_2}{R_1 + R_2}} \qquad \boxed{i_k = i \frac{\frac{1}{R_k}}{\frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_N}}}$$

Capacitor

- Charge accumulated on the plate is proportional to the voltage applied.

$$q \propto v \qquad i = \frac{dq}{dt} \qquad i = C\frac{dv}{dt}$$



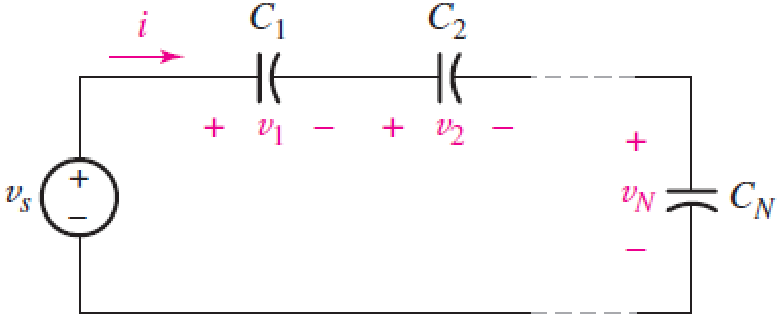
$$\boxed{v(t) = \frac{1}{C}\int_{t_0}^{t} i(t')\,dt' + v(t_0)}$$

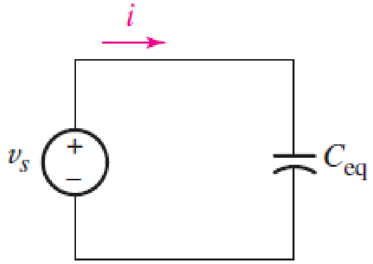
- Energy Storage:
- Power delivered to the Capacitor: $p = vi = Cv\dfrac{dv}{dt}$
- Integrating it over a period to determine the energy stored:

$$w_C(t) = \frac{1}{2}Cv^2$$

Capacitor combinations

Series





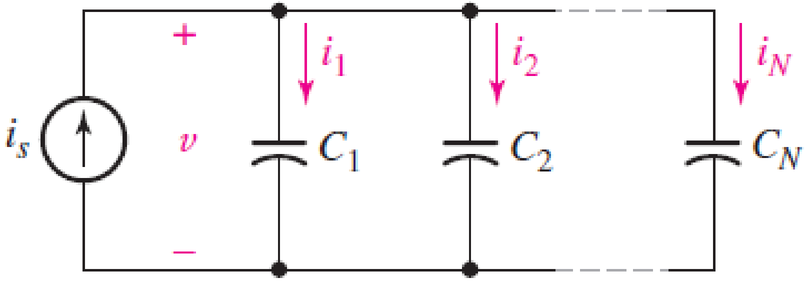
$$C_{eq} = \frac{1}{1/C_1 + 1/C_2 + \cdots + 1/C_N}$$

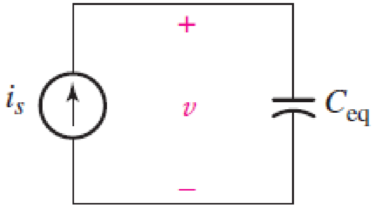
$$v_s = \sum_{n=1}^{N} v_n = \sum_{n=1}^{N} \left[\frac{1}{C_n} \int_{t_0}^{t} i\, dt' + v_n(t_0) \right]$$

$$= \left(\sum_{n=1}^{N} \frac{1}{C_n} \right) \int_{t_0}^{t} i\, dt' + \sum_{n=1}^{N} v_n(t_0)$$

$$v_s = \frac{1}{C_{eq}} \int_{t_0}^{t} i\, dt' + v_s(t_0)$$

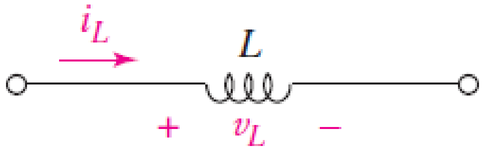
Parallel





$$C_{eq} = C_1 + C_2 + \cdots + C_N$$

Inductor



- Magnetic flux developed around a coil is proportional to the amount of current flowing through it.

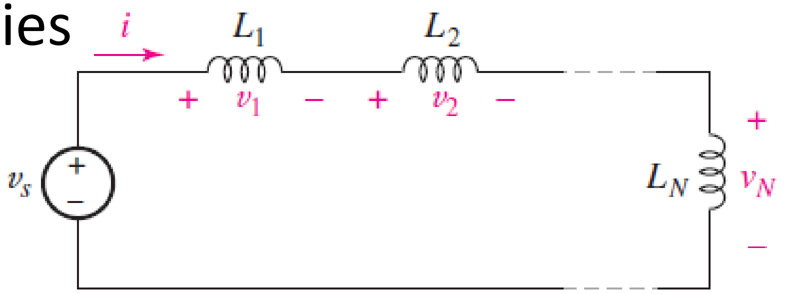
$$\psi \propto i \qquad v = \frac{d\psi}{dt} \qquad v = L\frac{di}{dt} \qquad \boxed{i(t) = \frac{1}{L}\int_{t_0}^{t} v\,dt' + i(t_0)}$$

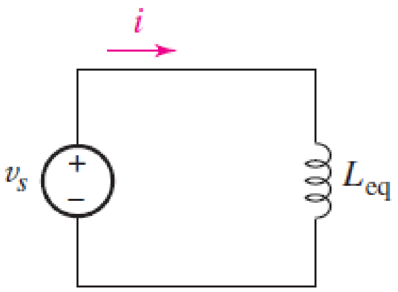
- Energy stored:
- Power Delivered to the inductor: $p = vi = Li\,\dfrac{di}{dt}$

$$\boxed{w_L(t) = \tfrac{1}{2}Li^2}$$

Inductor Combinations

Series



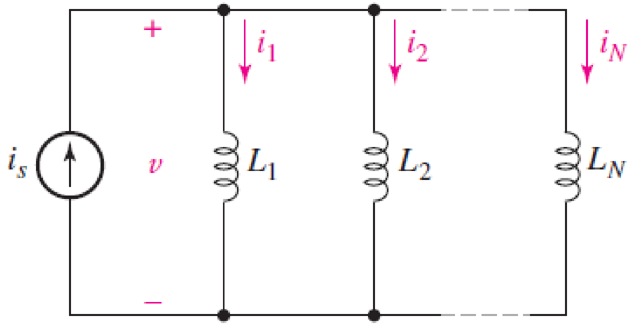


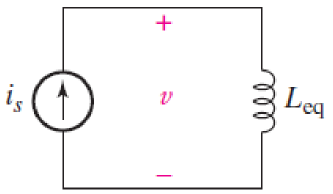
$$L_{eq} = L_1 + L_2 + \cdots + L_N$$

$$\begin{aligned} v_s &= v_1 + v_2 + \cdots + v_N \\ &= L_1 \frac{di}{dt} + L_2 \frac{di}{dt} + \cdots + L_N \frac{di}{dt} \\ &= (L_1 + L_2 + \cdots + L_N) \frac{di}{dt} \end{aligned}$$

$$v_s = \sum_{n=1}^{N} v_n = \sum_{n=1}^{N} L_n \frac{di}{dt} = \frac{di}{dt} \sum_{n=1}^{N} L_n$$

Parallel





$$i_s = \sum_{n=1}^{N} i_n = \sum_{n=1}^{N} \left[\frac{1}{L_n} \int_{t_0}^{t} v \, dt' + i_n(t_0) \right]$$

$$L_{eq} = \frac{1}{1/L_1 + 1/L_2 + \cdots + 1/L_N}$$