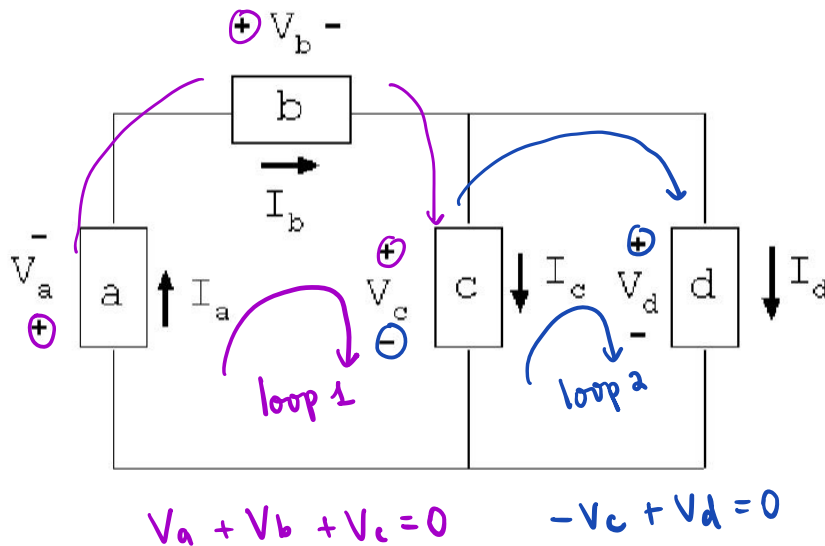


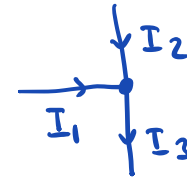
- Kirchhoff's voltage law (KVL): around any closed loop in a circuit,

$$\bullet \sum V_{rise} = \sum V_{drop} \Rightarrow \underline{\sum V_{drop} - \sum V_{rise} = 0}$$

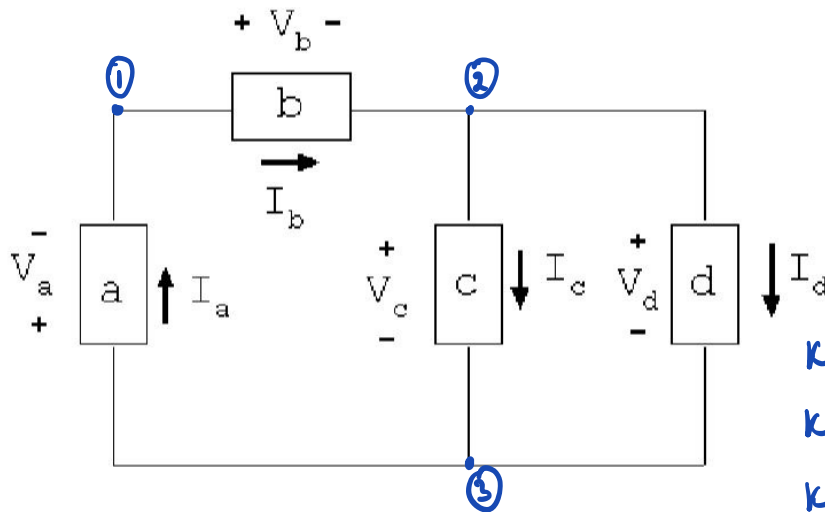


- Kirchhoff's current law (KCL): at any node in a circuit,

$$\sum I_{in} = \sum I_{out}$$



$$I_1 + I_2 = I_3$$

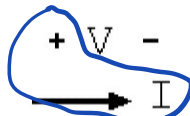
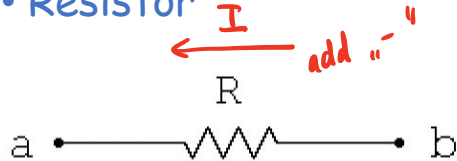


$$\text{KCL @ (1): } I_a = I_b$$

$$\text{KCL @ (2): } I_b = I_c + I_d$$

$$\text{KCL @ (3): } I_c + I_d = I_a$$

- Resistor



$V = RI$ ← Ohm's law
 (-I)

- V : voltage drop in the direction of current I
- R : resistance
 - $R \geq 0$
 - Units: Ohms (Ω) = $\frac{V}{A}$

- Special cases of an ideal resistor:

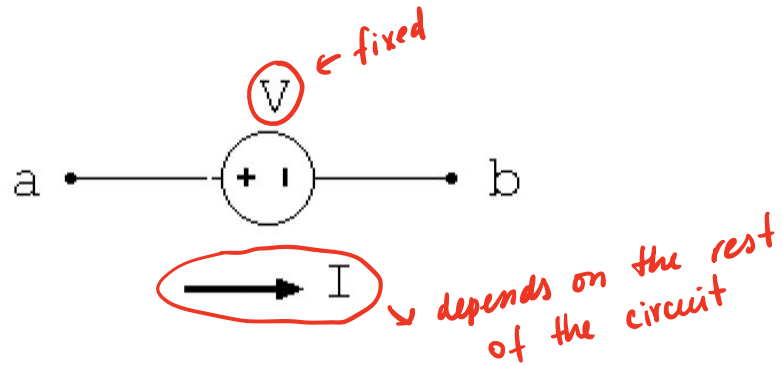
- $R = 0$: short-circuit element
 - $V = 0$, I : any



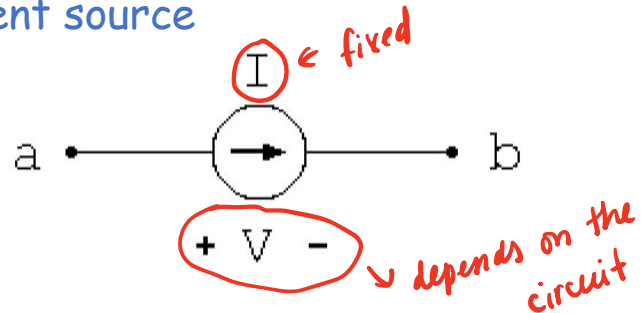
- $R = \infty$: open-circuit element
 - V : any, $I = 0$



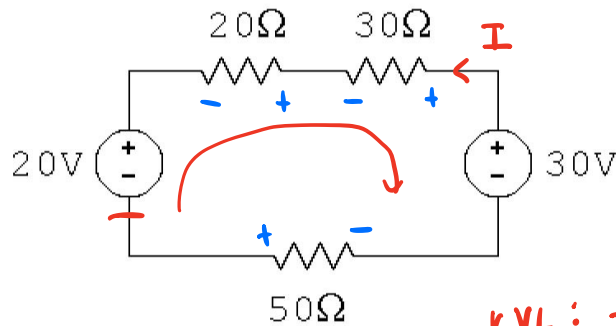
- Independent voltage source



- Independent current source



- Example #2: determine the current in the following circuit



- ① KVL
- ② Polarities

$$\text{KVL: } -20\text{V} - V_{20\Omega} - V_{30\Omega} + 30\text{V} - V_{50\Omega} = 0$$

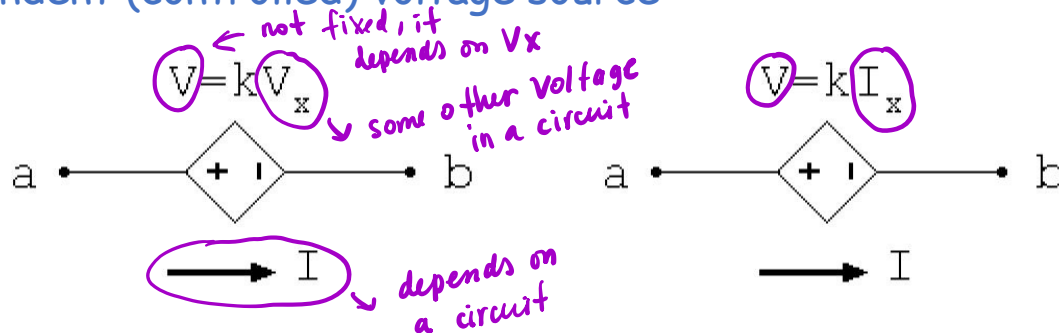
$$-20\text{V} - I \cdot 20 - I \cdot 30 + 30\text{V} - I \cdot 50 = 0$$

$$100I = 10$$

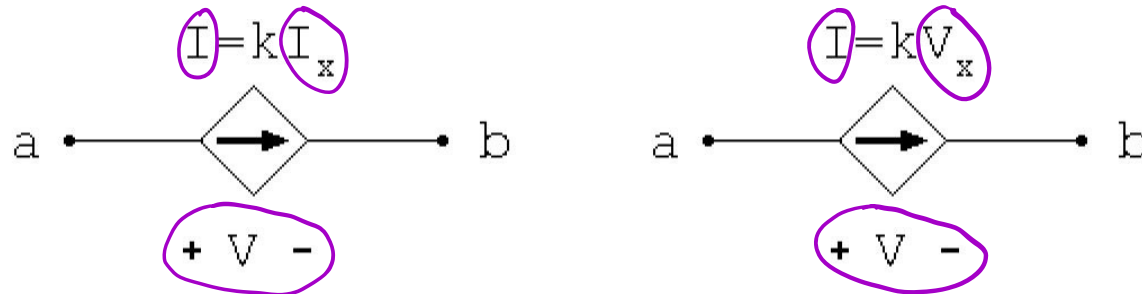
$$I = 0.1 \text{ A}$$

← units, please! 😊

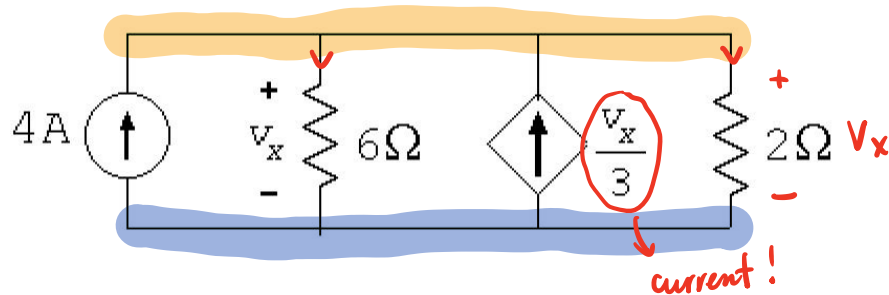
- Dependent (controlled) voltage source



- Dependent (controlled) current source



- Example #3: determine V_x in the following circuit

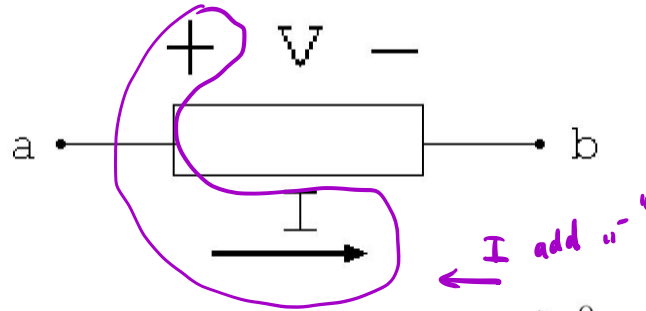


$$\text{KCL: } \sum I_{in} = \sum I_{out}$$

$$4A + \frac{V_x}{3} = I_{6\Omega} + I_{2\Omega} = \frac{V_x}{6} + \frac{V_x}{2}$$

$$V_x = 12V$$

- **Absorbed power:** total energy loss of charge carriers per unit time from "+" terminal to "-" terminal.



$$P = \frac{dW}{dt} = \frac{dW}{dq} \frac{dq}{dt} = VI$$

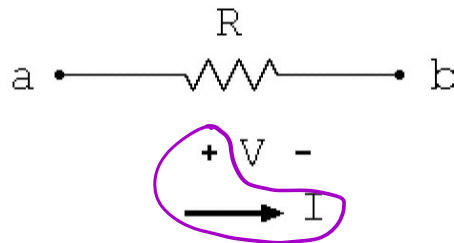
> 0 - absorbs power

$= 0$

< 0 - injects power
 (-I)

- **Units:** Watts (W) = $\frac{\text{Joule (J)}}{\text{second (s)}}$

- Absorbed power in resistor

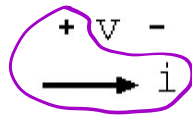
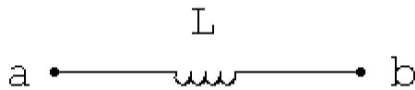


*Always absorbs power!
selfish ☺*

$$P = VI = (RI)I = \underline{I^2 R \geq 0}$$

$$P = VI = \left(\frac{V}{R}\right)V = \frac{V^2}{R} \geq 0$$

• Inductor



$$v(t) = L \frac{di}{dt}$$

\Rightarrow const $I \Rightarrow V=0 \rightarrow$ acts as a short circuit

• v : voltage drop in the direction of current I

• L : inductance

▪ $L \geq 0$

▪ Units: Henries (H)

• Absorbed power in inductor

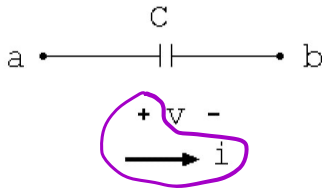
$$P = vi = \left(L \frac{di}{dt} \right) i = \frac{d}{dt} \left(\underbrace{\frac{1}{2} Li^2}_{\text{energy stored}} \right)$$

> 0 - energy \uparrow , taking energy

$= 0$

< 0 - energy \downarrow , giving energy.

- Capacitor



- v : voltage drop in the direction of current I

- C : capacitance

- $C \geq 0$

- Units: Farads (F)

$$i(t) = C \frac{dv}{dt}$$

constant $V \Rightarrow I=0 \rightarrow$ acts as open-circuit

- Absorbed power in capacitor

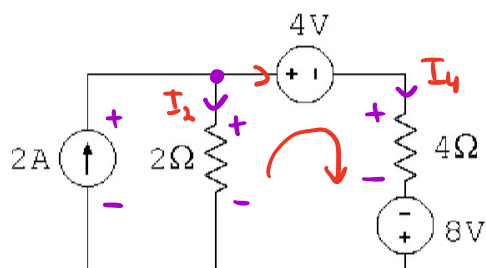
$$\underline{P = vi} = v \left(C \frac{dv}{dt} \right) = \frac{d}{dt} \left(\frac{1}{2} C v^2 \right)$$

> 0 - taking energy

$= 0$

< 0 - giving energy

- **Example #4:** determine the absorbed power in each element in the following circuit



$$\text{KCL: } 2 = I_{2\Omega} + I_{4V} \quad ①$$

$$\text{KVL: } -V_{2\Omega} + 4V + V_{4\Omega} - 8V = 0$$

$$- I_{2\Omega} \cdot 2 + 4 + I_{4\Omega} \cdot 4 - 8 = 0 \quad ②$$

$$I_{2\Omega} = \frac{2}{3} \text{ A} \quad I_{4\Omega} = \frac{4}{3} \text{ A}$$

$$P_{2\Omega} = R \cdot I_{2\Omega}^2 = 2 \cdot \left(\frac{2}{3}\right)^2 = \frac{8}{9} \text{ W}$$

$$P_{4\Omega} = R \cdot I_{4\Omega}^2 = 4 \cdot \left(\frac{4}{3}\right)^2 = \frac{64}{9} \text{ W}$$

$$\sum P = 0$$

$$\left\{ \begin{array}{l} P_{4V} = V_{4V} \cdot I_{4V} = 4 \cdot \frac{4}{3} = \frac{16}{3} \text{ W} > 0 \rightarrow \text{absorbing} \\ P_{8V} = V_{8V} \cdot (-I_{4\Omega}) = 8 \cdot \left(-\frac{4}{3}\right) = -\frac{32}{3} \text{ W} < 0 \\ P_{2A} = V_{2A} \cdot (-2) = (I_{2\Omega} \cdot 2) \cdot (-2) = -\frac{8}{3} \text{ W} < 0 \end{array} \right. \quad \left. \begin{array}{l} \\ \\ \end{array} \right\} \text{injecting}$$

Summary

- Current and voltage
- Series and parallel configurations, SRS
- Absorbed power
- Kirchhoff's voltage and current laws (KVL and KCL)
- Ideal Resistors, Ohm's law
- Independent and dependent sources
- Ideal Capacitors and inductors
- Obtain voltages, currents and absorbed power in basic circuits using KVL, KCL and Ohm's law