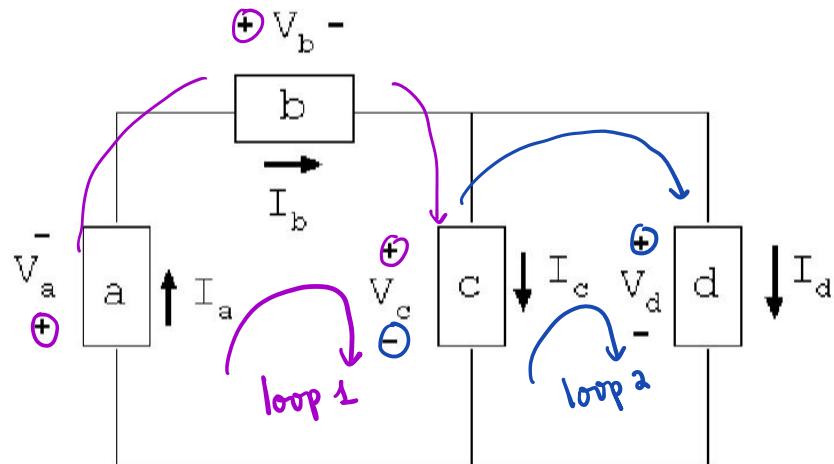


- Kirchhoff's voltage law (KVL): around any closed loop in a circuit,

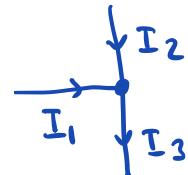
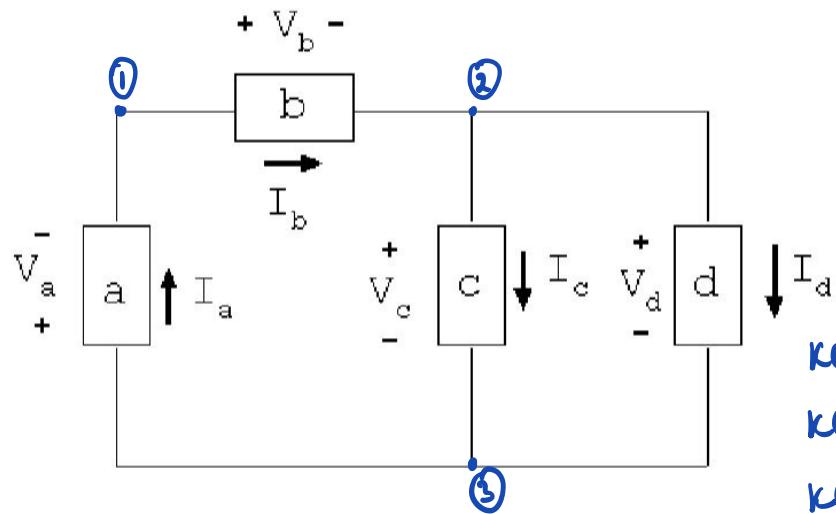
$$\bullet \sum V_{rise} = \sum V_{drop} \Rightarrow \underbrace{\sum V_{drop} - \sum V_{rise}}_{} = 0$$



$$V_a + V_b + V_c = 0 \quad -V_c + V_d = 0$$

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

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



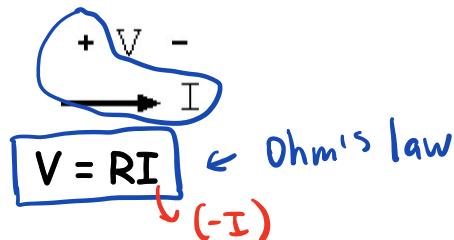
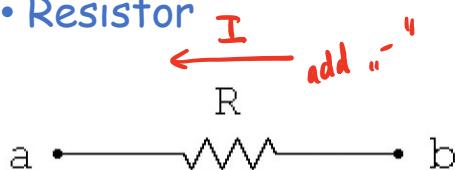
$$I_1 + I_2 = I_3$$

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

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

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

- Resistor



- V : 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

- $V = 0, I: \text{any}$

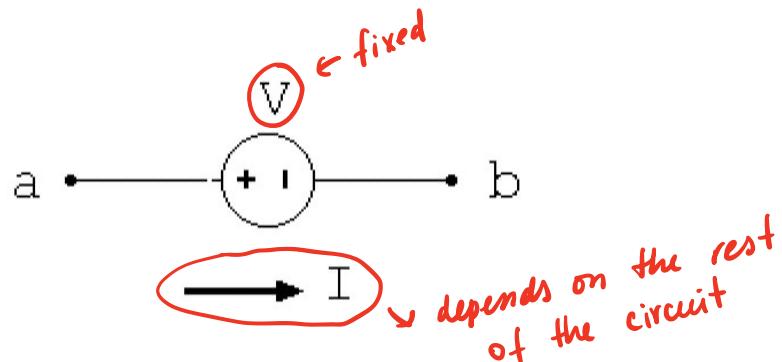


- $R = \infty$: open-circuit element

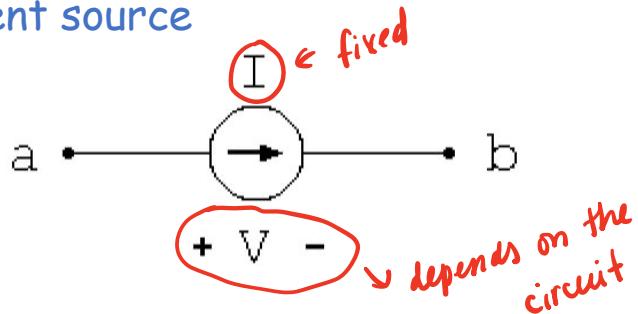
- $V: \text{any}, I=0$



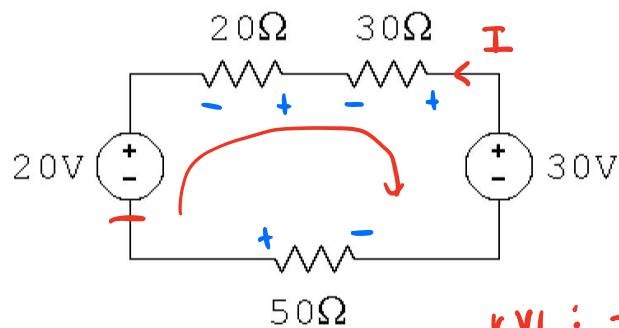
- Independent voltage source



- Independent current source



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



① KVL
② Polarities

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

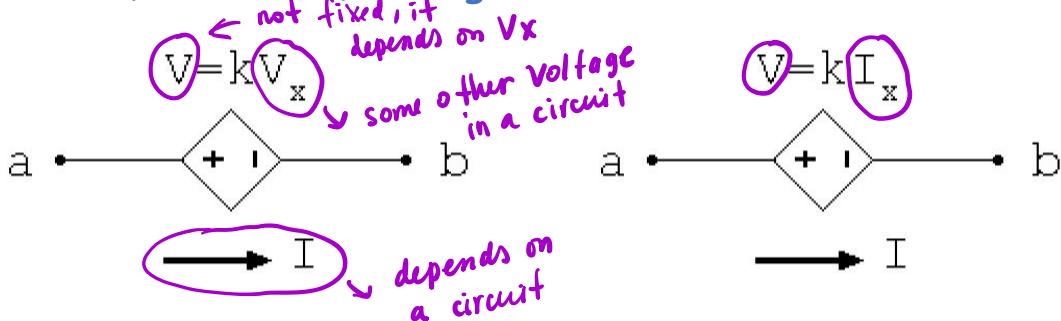
$$-20V - I \cdot 20 - I \cdot 30 + 30V - I \cdot 50 = 0$$

$$100I = 10$$

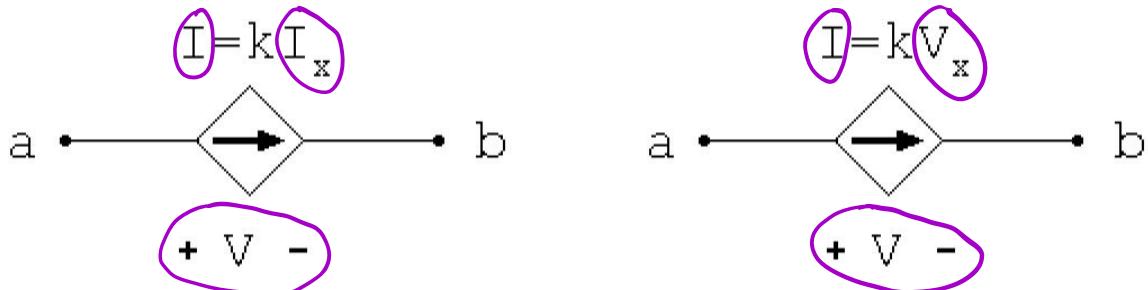
$$I = 0.1 \text{ A}$$

← Units, please! ☺

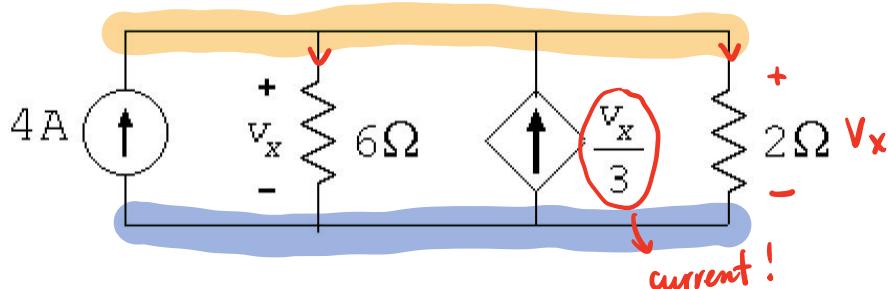
- Dependent (controlled) voltage source



- Dependent (controlled) current source



- Example #3: determine V_x in the following circuit

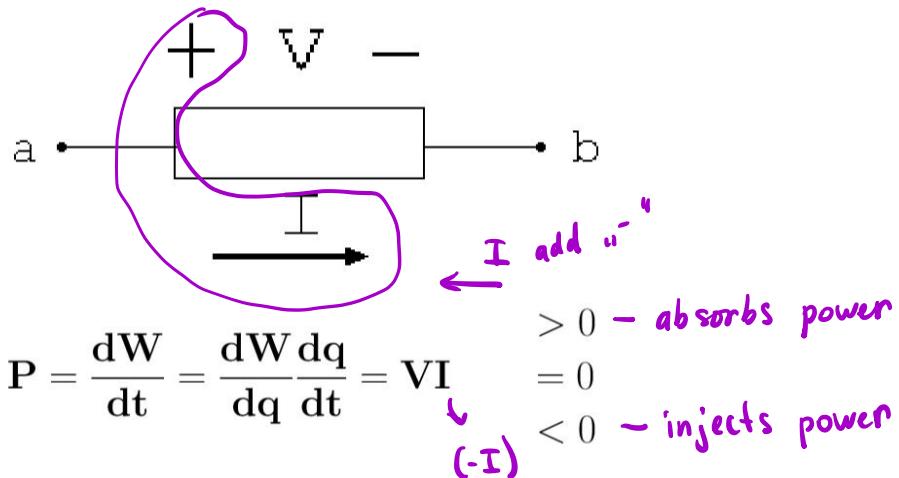


$$KCL: \sum I_{in} = \sum I_{out}$$

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

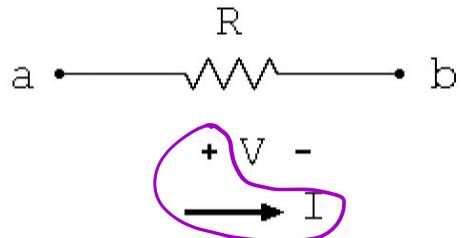
$$V_x = 12V$$

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



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

- Absorbed power in resistor

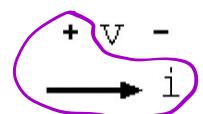
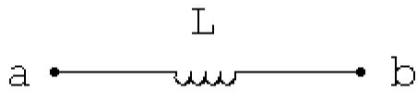


Always absorbs power!
selfish ☺

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

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

- Inductor



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

- v : voltage drop in the direction of current I

- L : inductance

- $L \geq 0$

- Units: Henries (H)

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

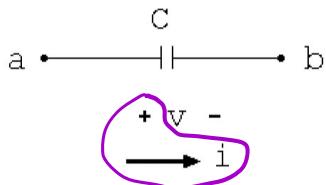
- Absorbed power in inductor

$$P = vi = \left(L \frac{di}{dt} \right) i = \underbrace{\frac{d}{dt} \left(\frac{1}{2} L i^2 \right)}_{\text{energy stored}} > 0 \quad - \text{energy } \uparrow, \text{ taking energy}$$

$$= 0$$

$$< 0 \quad - \text{energy } \downarrow, \text{ giving energy.}$$

- Capacitor



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

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

- v : voltage drop in the direction of current I

- C : capacitance

- $C \geq 0$

- Units: Farads (F)

- Absorbed power in capacitor

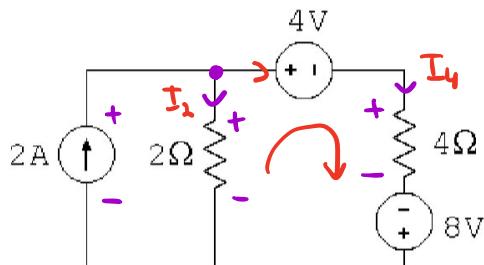
$$P = vi = v \underbrace{\left(C \frac{dv}{dt} \right)}_{\text{;}} = \frac{d}{dt} \left(\frac{1}{2} Cv^2 \right)$$

> 0 - taking energy

$= 0$

< 0 - giving energy

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



$$KCL: 2 = I_{2A} + I_{4A} \quad \textcircled{1}$$

$$KVL: -V_{2A} + 4V + V_{4A} - 8V = 0$$

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

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

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

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

$$\sum P = 0$$

$$\left\{ \begin{array}{l} P_{4V} = V_{4V} \cdot I_4 = 4 \cdot \frac{4}{3} = \frac{16}{3} W > 0 \rightarrow \text{absorbing} \\ P_{8V} = V_{8V} \cdot (-I_4) = 8 \cdot \left(-\frac{4}{3}\right) = -\frac{32}{3} W < 0 \end{array} \right.$$

$$\left\{ \begin{array}{l} P_{8V} = V_{8V} \cdot (-I_4) = 8 \cdot \left(-\frac{4}{3}\right) = -\frac{32}{3} W < 0 \\ P_{2A} = V_{2A} \cdot (-2) = (I_{2A} \cdot 2) \cdot (-2) = -\frac{8}{3} W < 0 \end{array} \right. \quad \text{injecting} \curvearrowleft$$

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