ESc201: Introduction to Electronics

Circuit Fundamentals

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Examination Schedule

- Quiz1: Thursday, <u>Sept. 01, 2022</u>, 8.00-8.50 AM in the tutorial hour
- Quiz2: Thursday, <u>Oct. 13, 2022</u>, 8.00-8.50 AM in the tutorial hour
- Mid-semester examination: Week of Sept. 19-Sept. 24, 2022
- Quiz3: Thursday, <u>Nov. 10, 2022</u>, 8.00-8.50 AM in the tutorial hour
- End-semester Examination: Nov. 17- Nov. 26, 2022

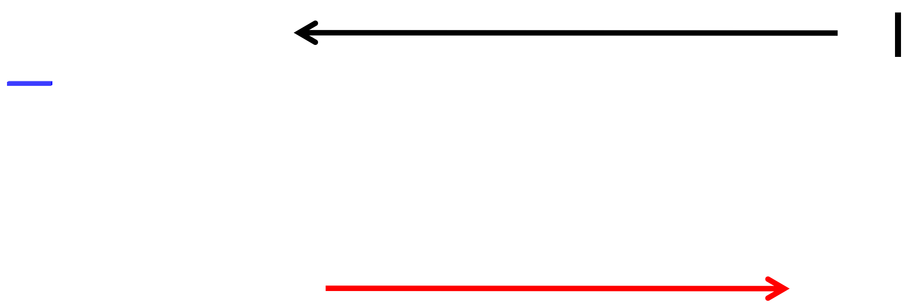
- **<u>Extra Class</u>**: Thursday, <u>Aug. 04, 2022</u>, 8.00-8.50 AM, L20

Today’s agenda

- Power and Energy
- Kirchhoff’s current and voltage laws

Recap

- Current is time rate of flow of electrical charge $i(t) = \dfrac{dq(t)}{dt}$
- Units are amperes (A), equivalent to coulombs/second (*C/s)*
- Current has a magnitude and a direction

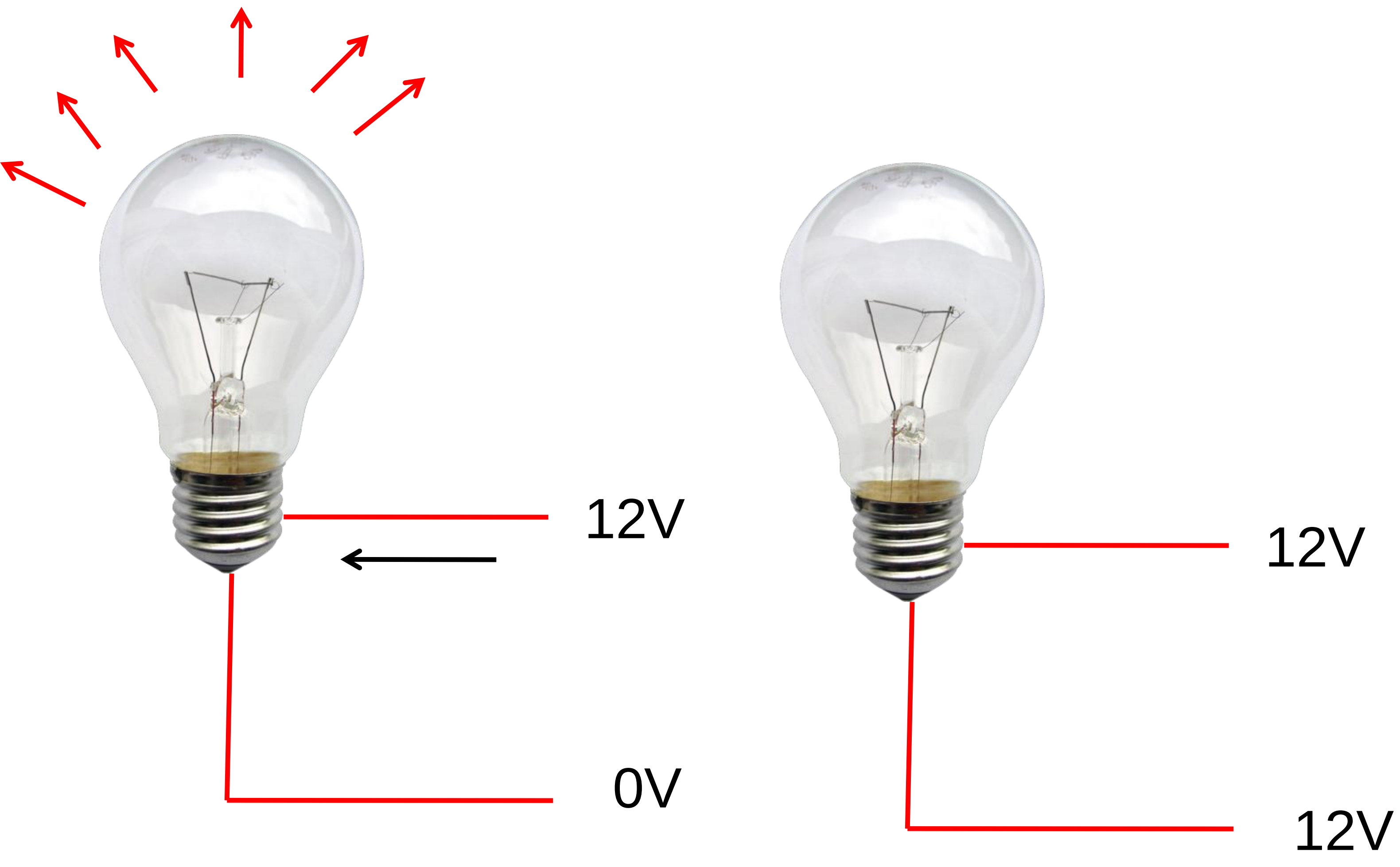


10^{16} electrons flow per second

Direction of current flow is opposite to that of electron flow

Recap

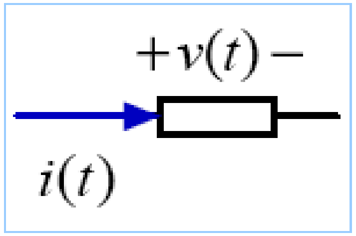
- Voltage difference causes current to flow
- Potential difference between two points: Work done to move unit positive charge between two points
- Units of Voltage: volt (V)



Recap

Resistance

R



Ohm's law $$v(t) = R \times i(t)$$

$$R = \frac{v}{i}$$

$$G = \frac{i}{v}$$

Conductance

G = 1/R

$$i(t) = \frac{v(t)}{R} = G \times v(t)$$

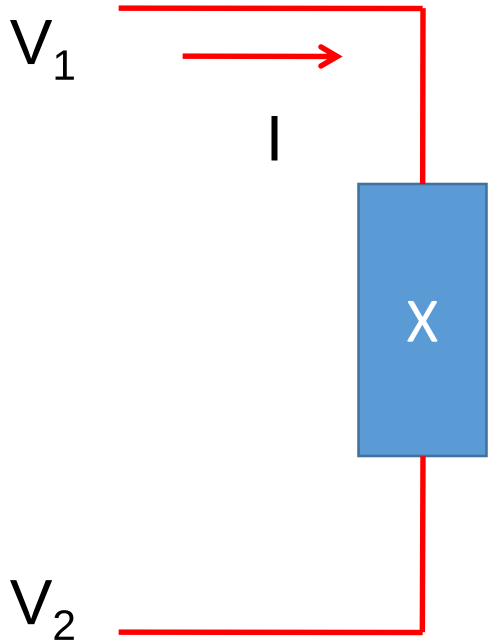
Power and Energy

- Energy is ability to work; SI unit of joule [**J**]
- Power = rate of energy use/generation: *dw/dt*
  - Units is Watts = Joule/Sec

$$P(t) = \frac{dw}{dt} = \frac{dw}{dq}\frac{dq}{dt} = v(t)\,i(t)$$

$$P(t) = \frac{dw}{dt} \Longrightarrow \qquad w = \int_{t1}^{t2} p(t)\,dt$$

Power



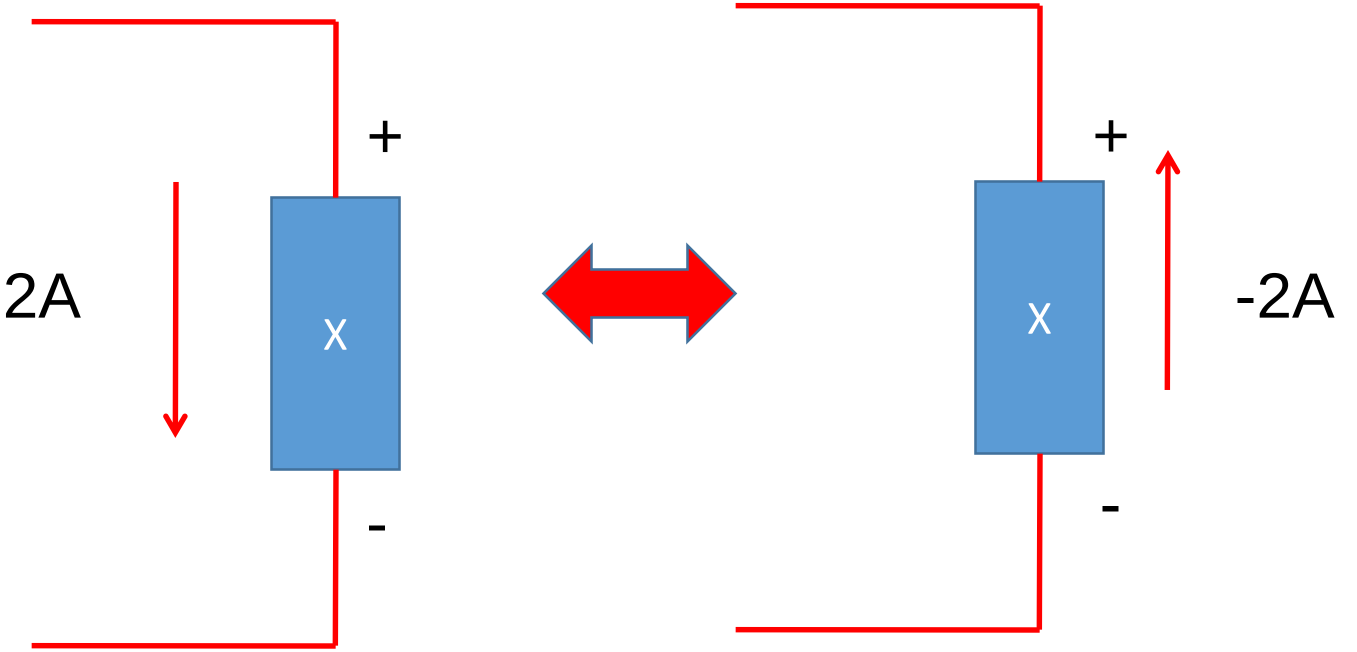
$$P = (V_1 - V_2) \times I$$

If $V_1 > V_2$ then P is positive and it means that power is being delivered to the electrical element X

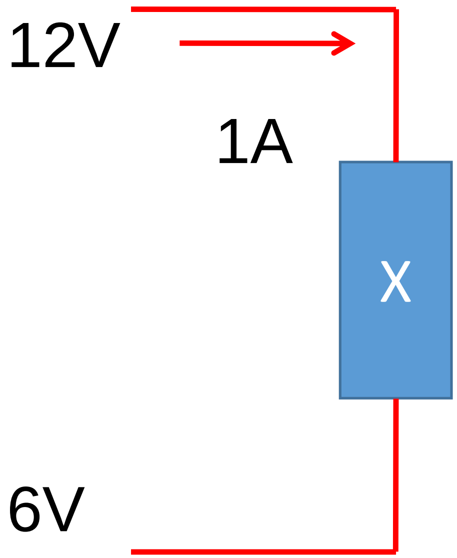
If $V_1 < V_2$ then P is negative and it means that power is being extracted from the electrical element X.

X is a source of power !

Note on direction of current

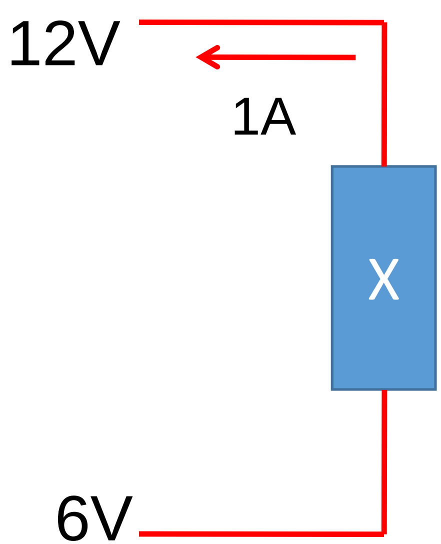


Examples of power consumption/supply



P = ?

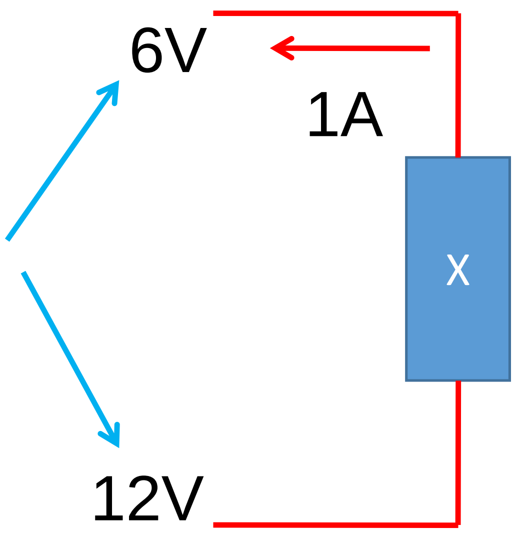
$$P = (V_1 - V_2) \times I$$
$$= (12 - 6) \times 1 = 6W$$



P = ?

$$P = (V_1 - V_2) \times I$$
$$= (12 - 6) \times -1 = -6W$$

Power is supplied by element X instead of consumption

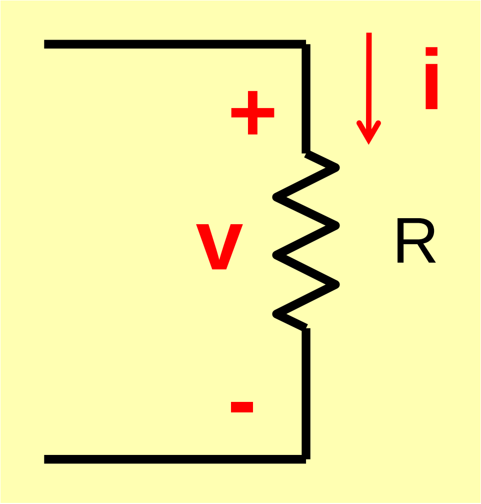


P = ?

$$P = (V_1 - V_2) \times I$$
$$= (6 - 12) \times -1 = 6W$$

Power is being delivered to the electrical element X

Power dissipated in a Resistor



$$v = i \times R$$

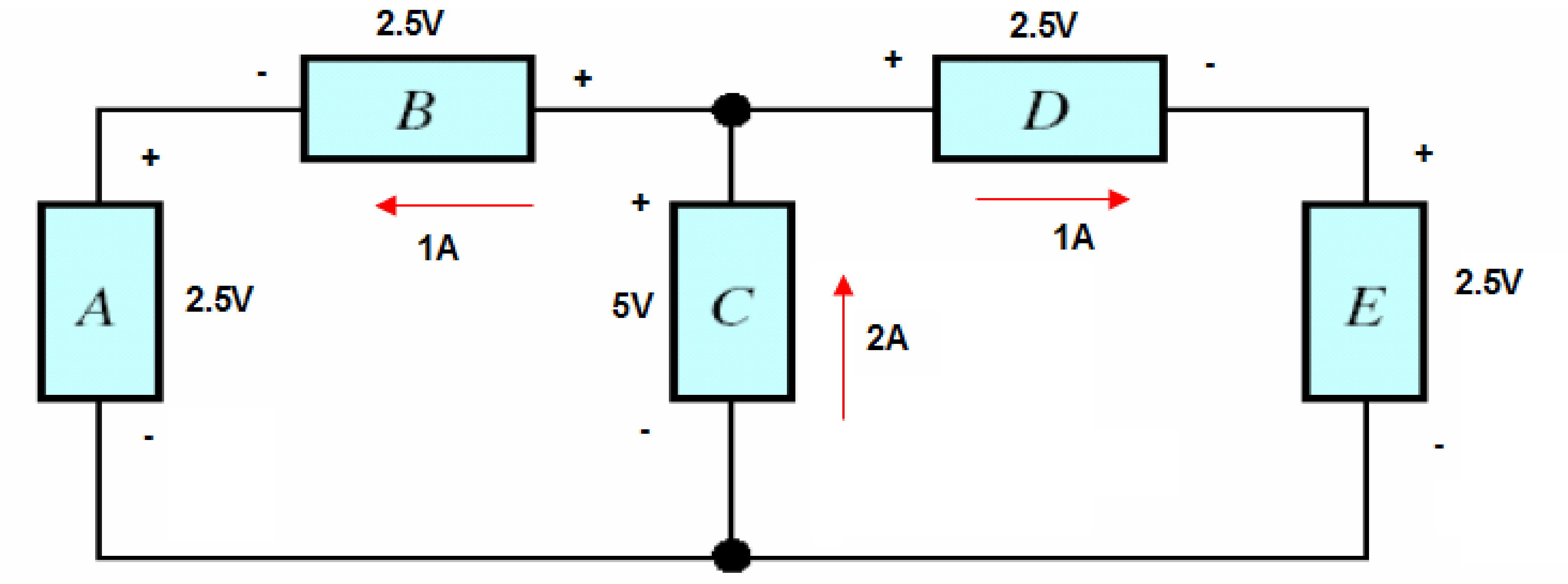
$$i = \frac{v}{R}$$

$$P = v \times i$$

$$P = i^2 \times R$$

$$P = \frac{v^2}{R}$$

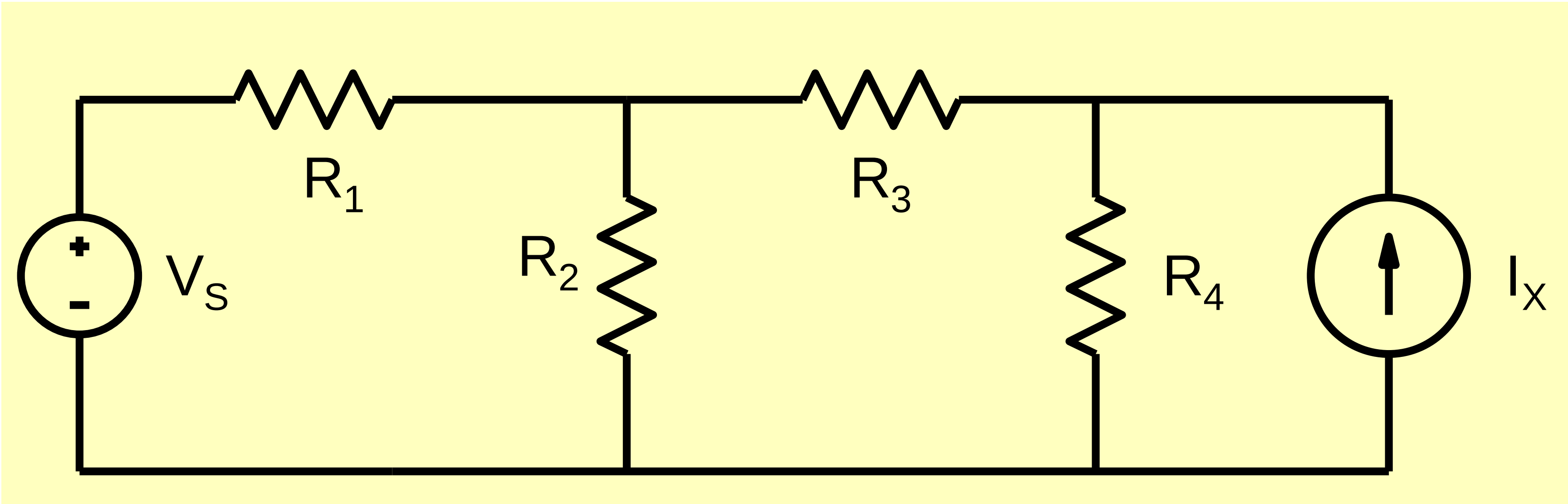
There is only one battery in the circuit. Can you find which element is a battery?



A battery is a source of power, so power dissipated is negative

Answer is C

Circuit Analysis

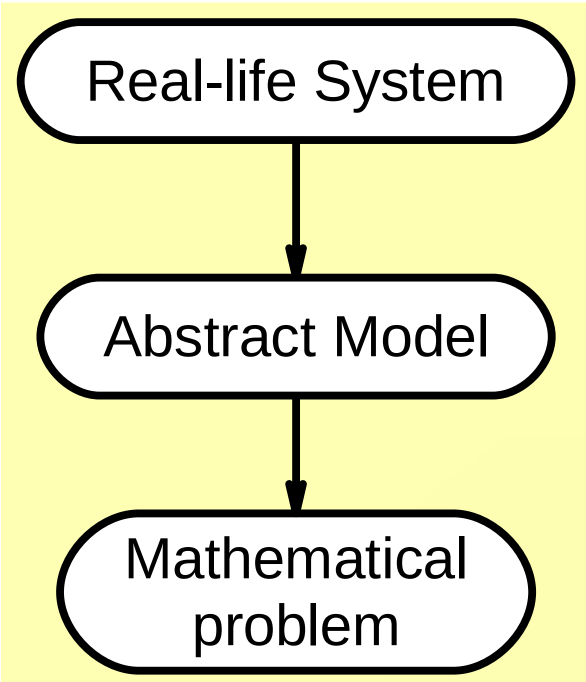


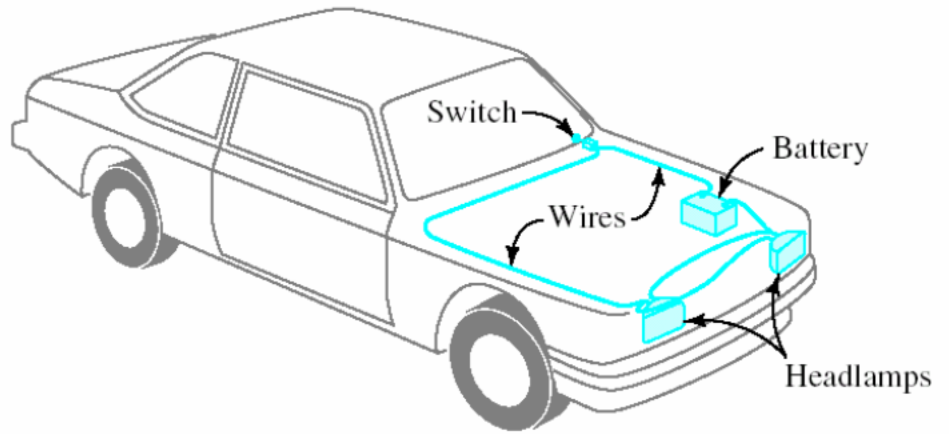
What is current in R_2 ?

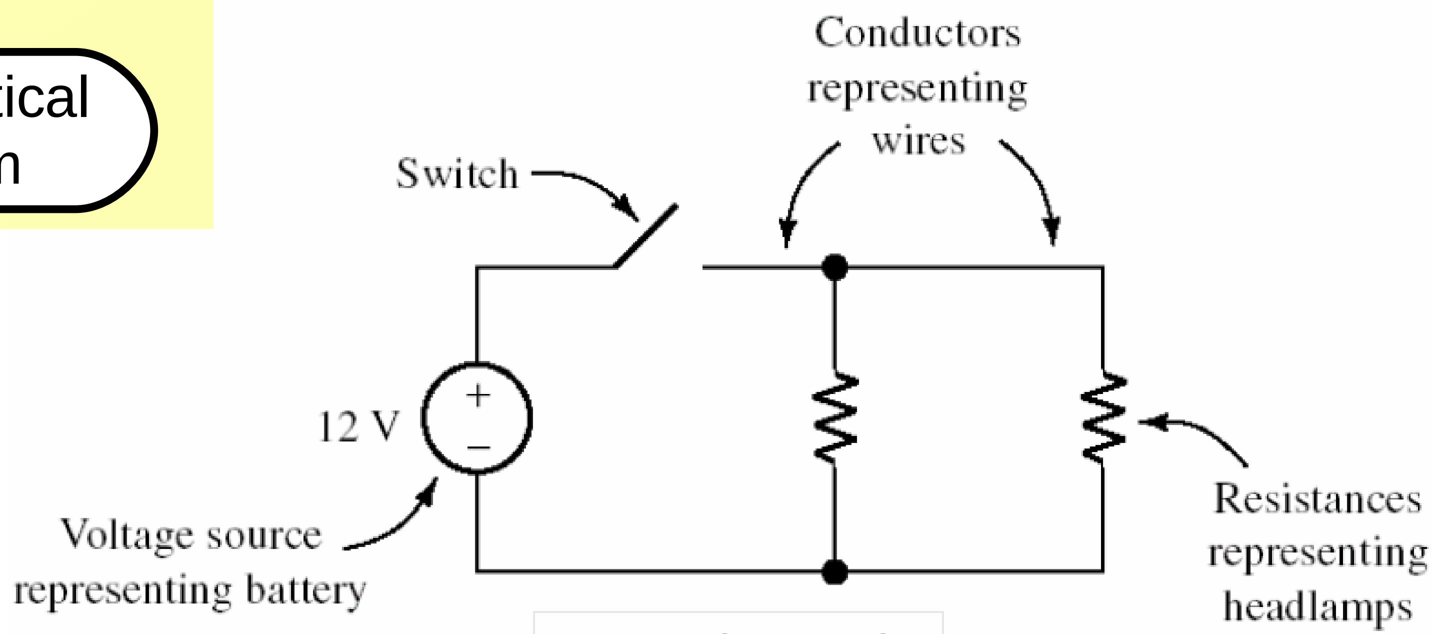
Procedure:

Use Kirchhoff's voltage law (KVL) and Kirchhoff's Current law (KCL) to transform the circuit into a set of equations whose solution gives the required voltage or current value

Engineering Analysis



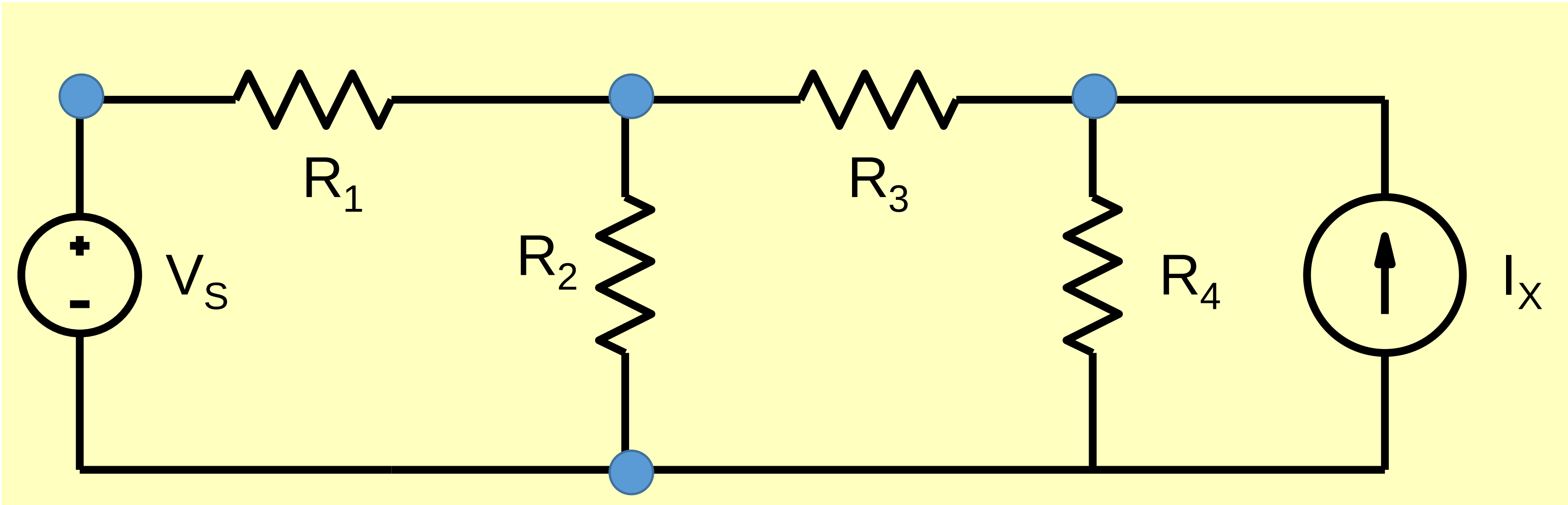




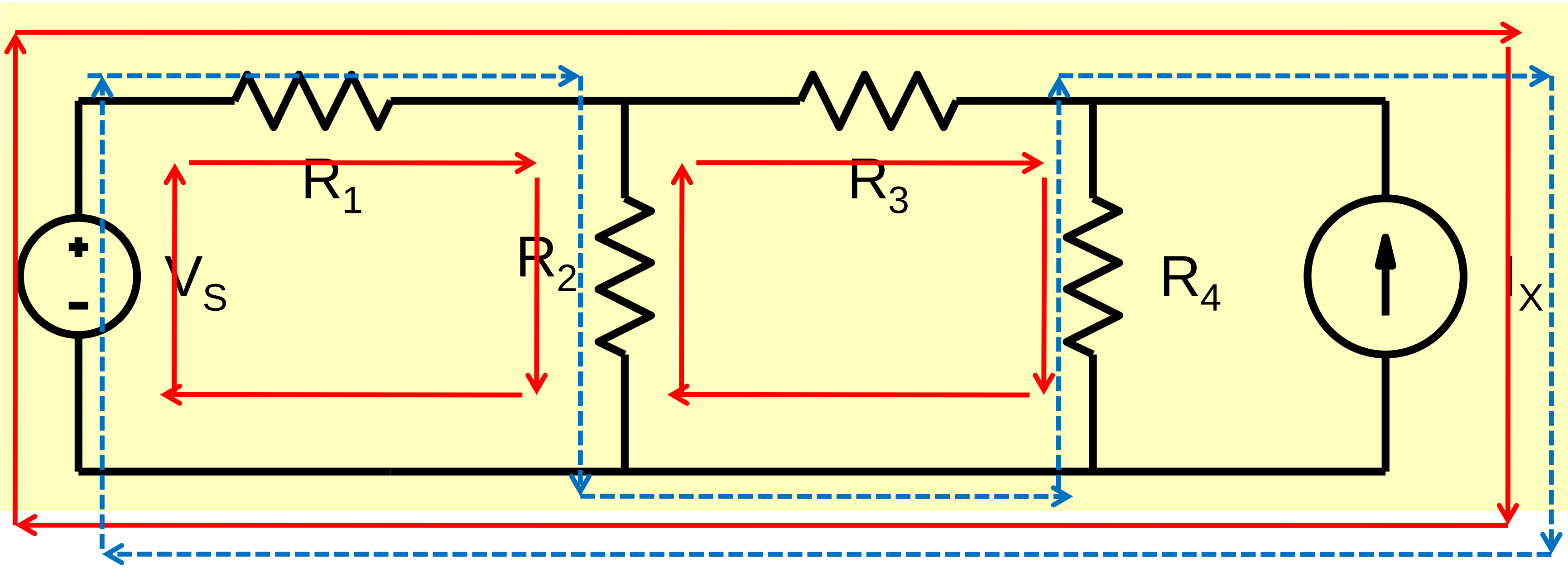
$$P = \frac{v^2}{R_1} + \frac{v^2}{R_2}$$

Nodes and loops

Node: A point where 2 or more circuit elements are connected.



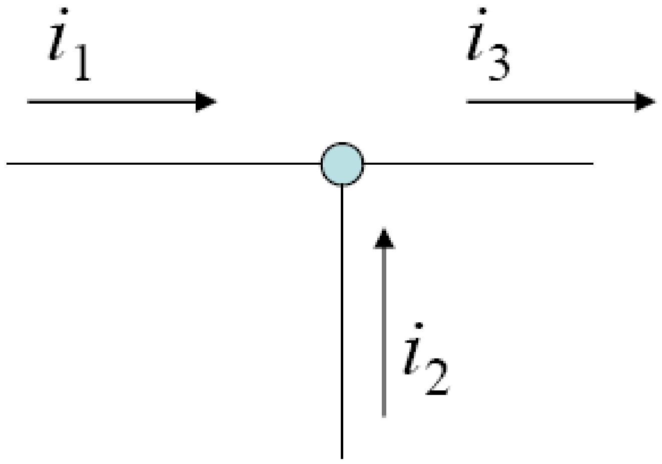
A ***loop is formed by tracing a closed path*** through circuit elements without passing through any intermediate node more than once



This is not a valid loop !

Kirchhoff's Current Law (KCL)

Sum of currents entering a node is equal to sum of currents leaving a node



$$\boxed{i_1 + i_2 = i_3}$$

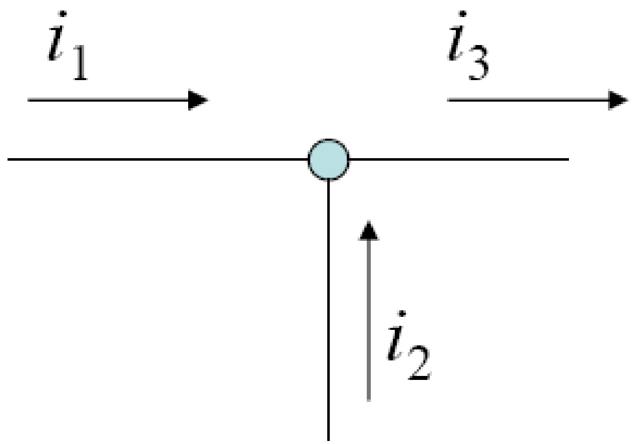
Conservation of charge!

Kirchhoff's Current Law (KCL)

Net current entering a node is zero

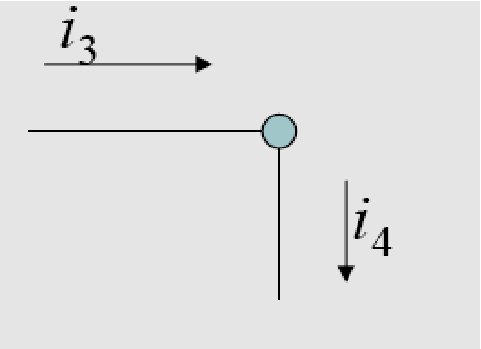
$$\sum_{1}^{N} i_j = 0$$

Current entering a node is considered positive and current leaving a node is considered as negative

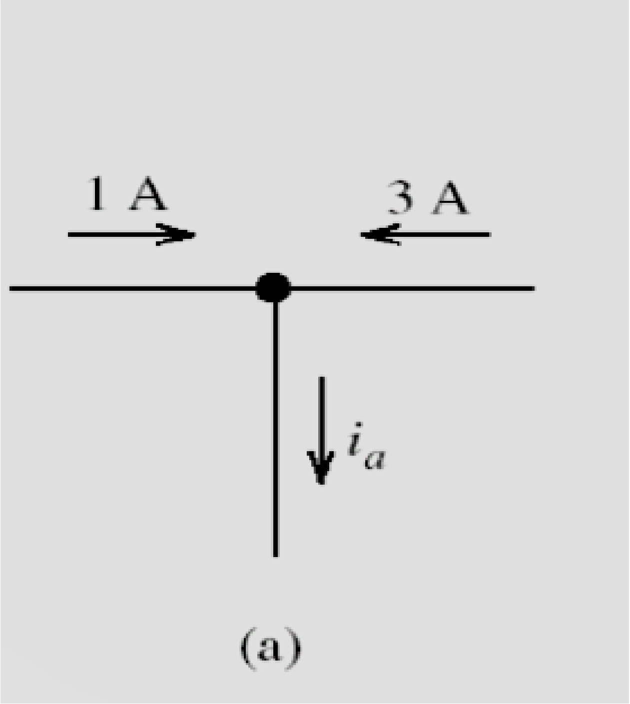


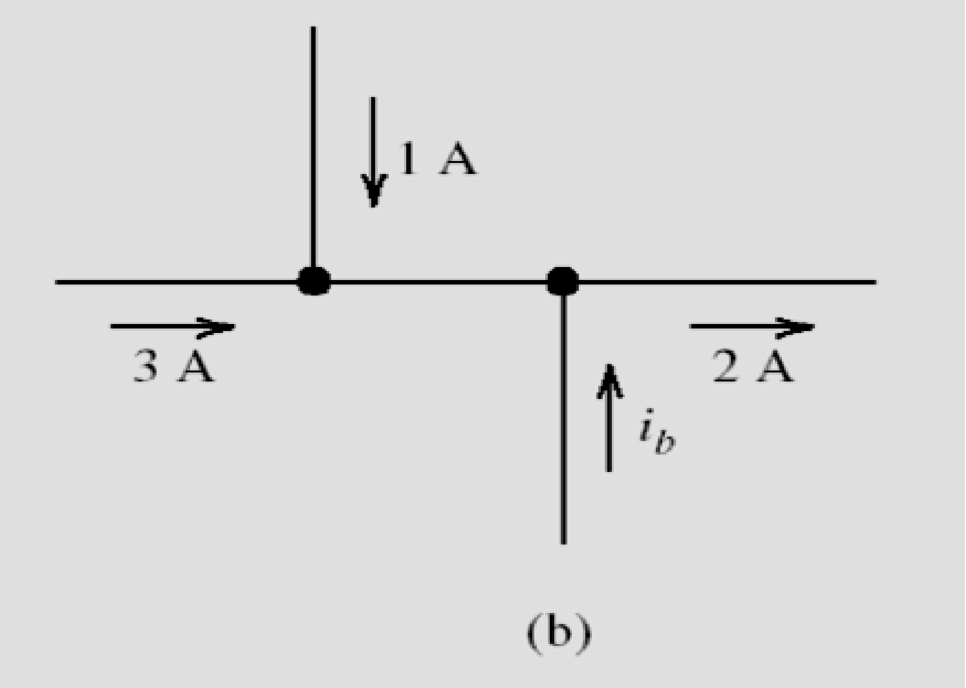
$$i_1 + i_2 - i_3 = 0$$

Examples:



$$i_3 = i_4$$





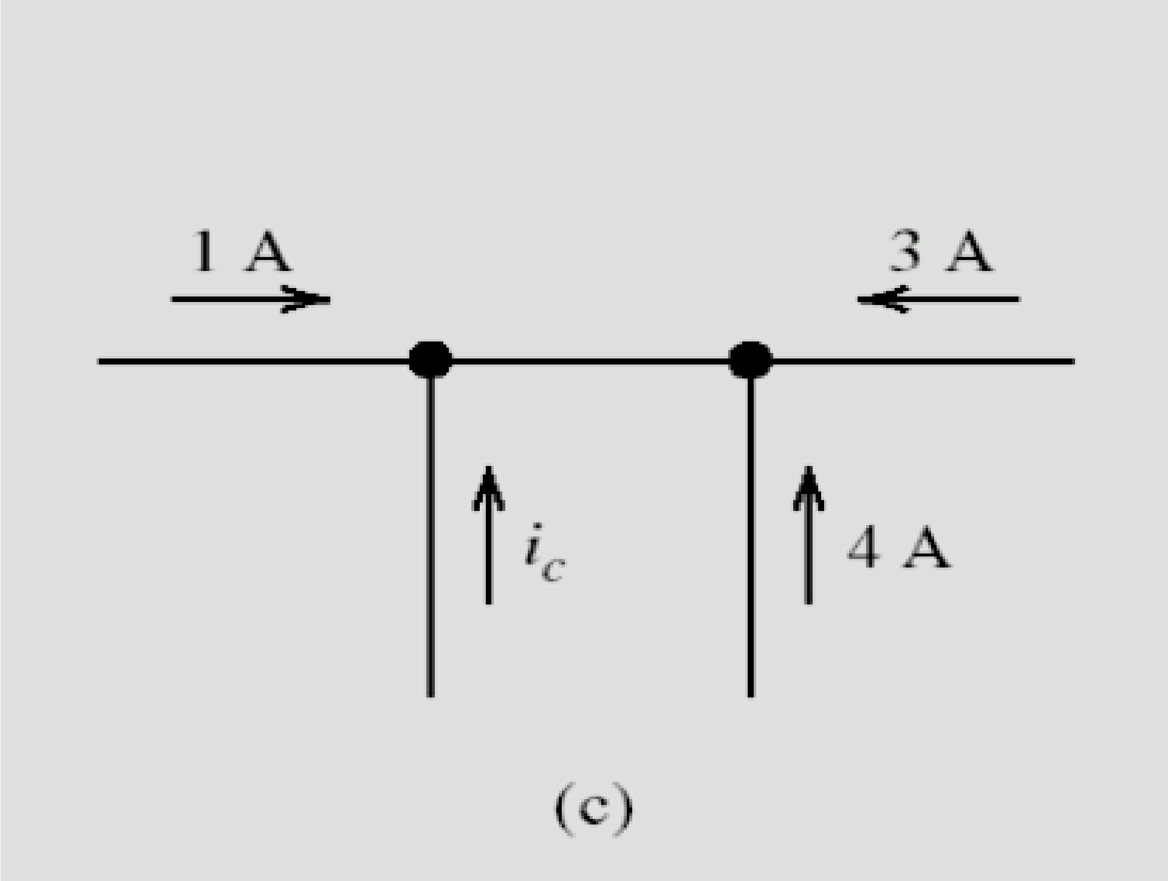
$$1 + 3 - i_a = 0$$

$$i_a = 4A$$

$$1 + 3 + i_b - 2 = 0$$

$$i_b = -2A$$

Examples:

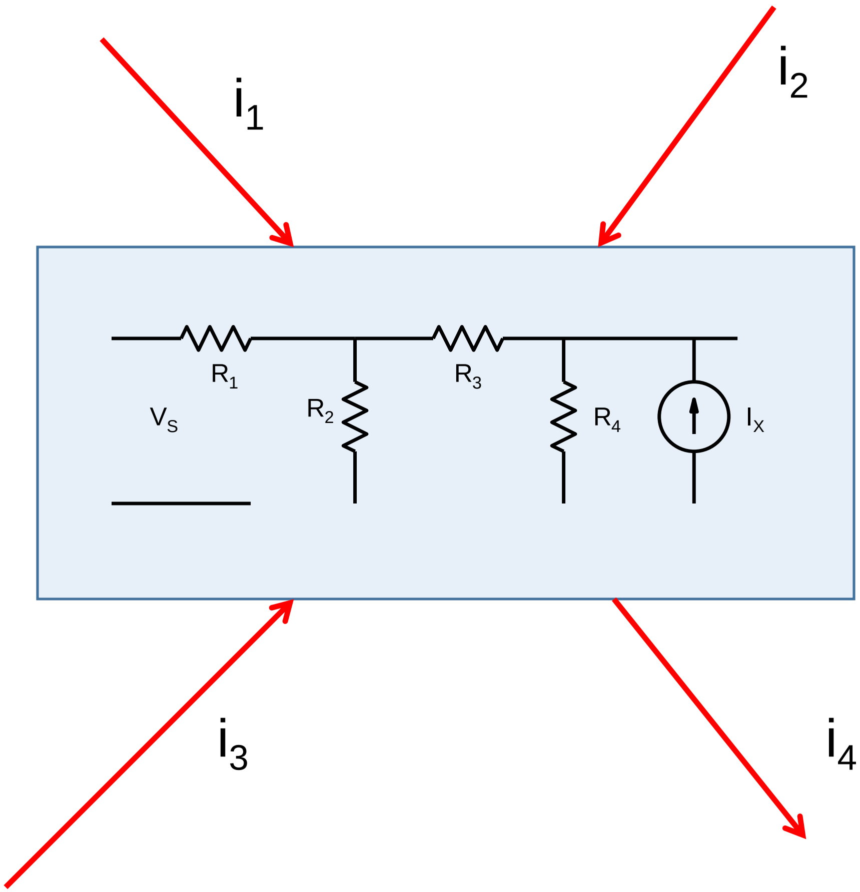


$$1 + 3 + i_c + 4 = 0$$

$$i_c = -8A$$

KCL: More general formulation

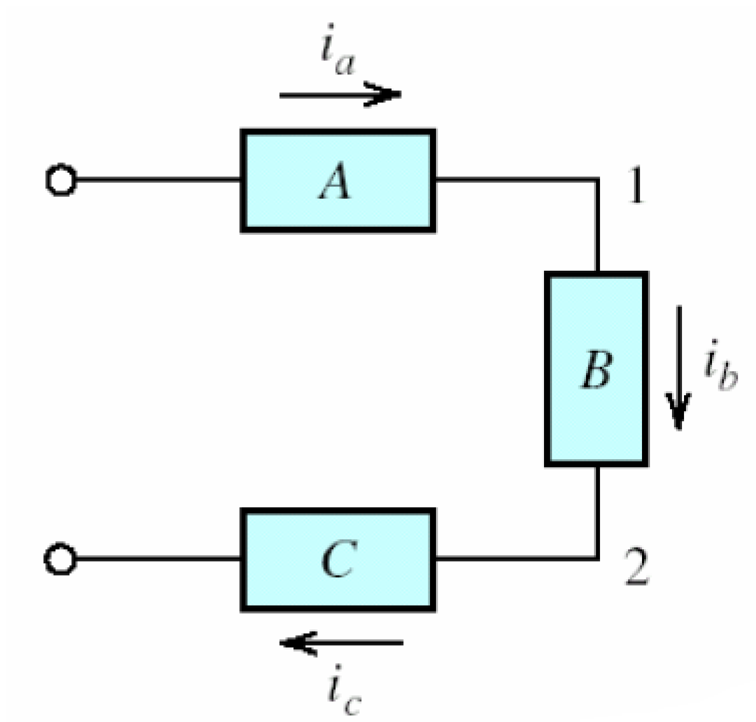
The sum of currents entering/leaving a **closed surface is zero.**



$$i_1 + i_2 + i_3 - i_4 = 0$$

Series Circuit

Two elements are connected in series if there is no other element connected to the node joining them



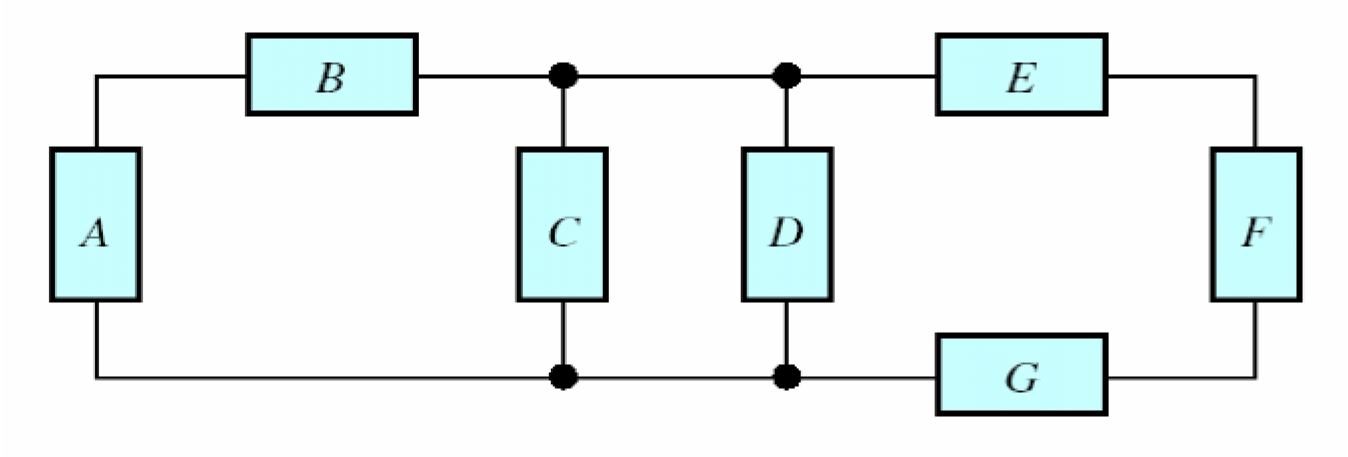
A, B and C are in series

The elements have the same current going through them

$$i_a = i_b = i_c$$

Example:

Identify the groups of elements connected in series



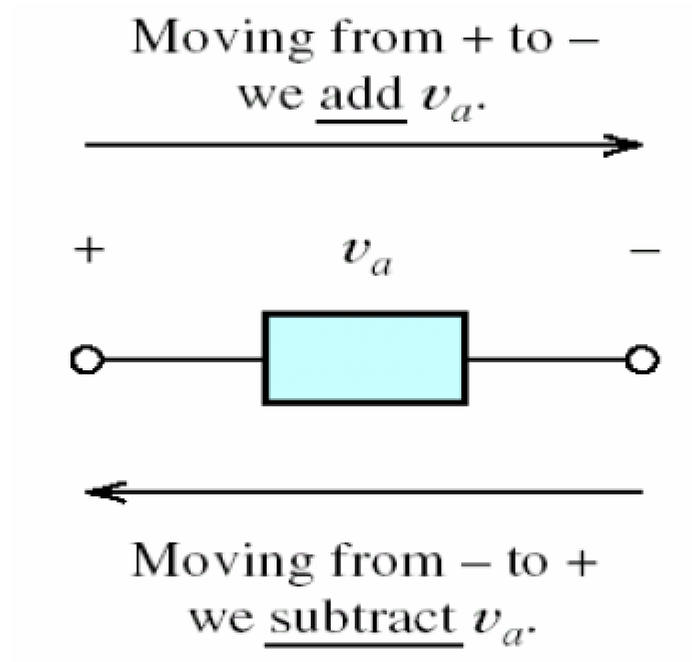
A and B are in series

E, F and G are in series

Kirchhoff's Voltage Law (KVL)

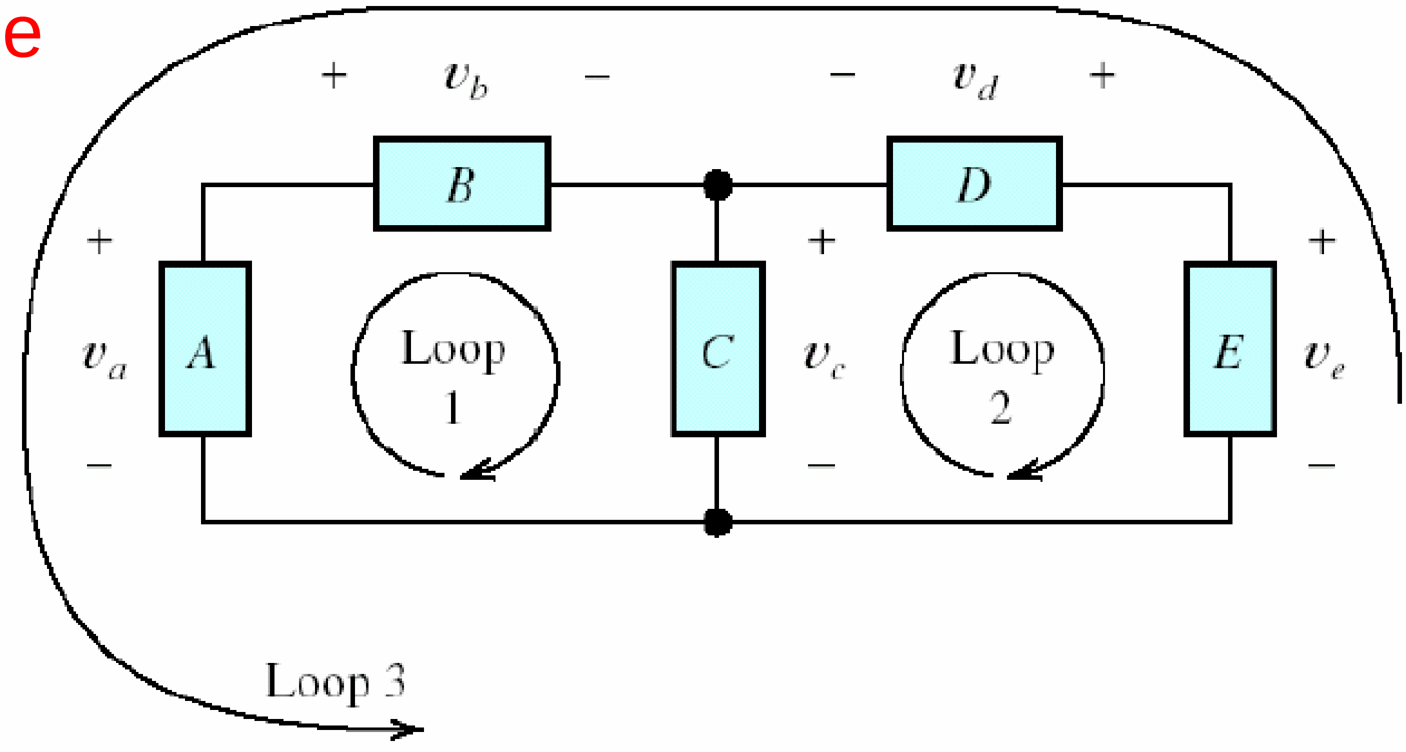
The algebraic sum of the voltages equals zero for any closed path (loop) in an electrical circuit

In applying KVL to a loop, voltages are added or subtracted depending on their reference polarities relative to the direction of travel around the loop.



Conservation of energy!

Example



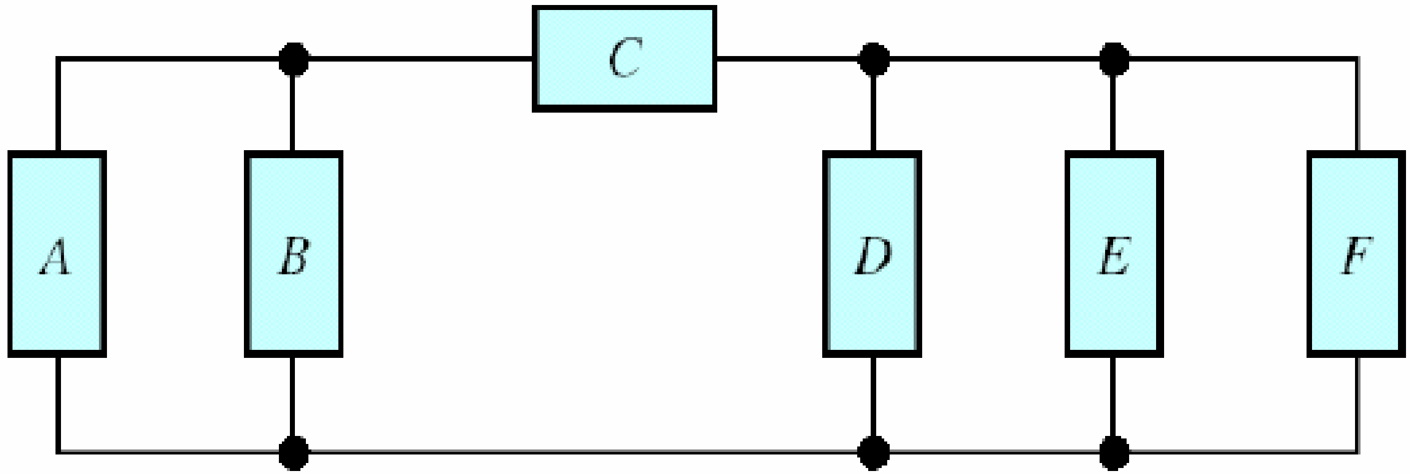
$$\text{Loop1}: -v_a + v_b + v_c = 0$$

$$\text{Loop2}: -v_c - v_d + v_e = 0$$

$$\text{Loop3}: -v_e + v_d - v_b + v_a = 0$$

Parallel Circuits

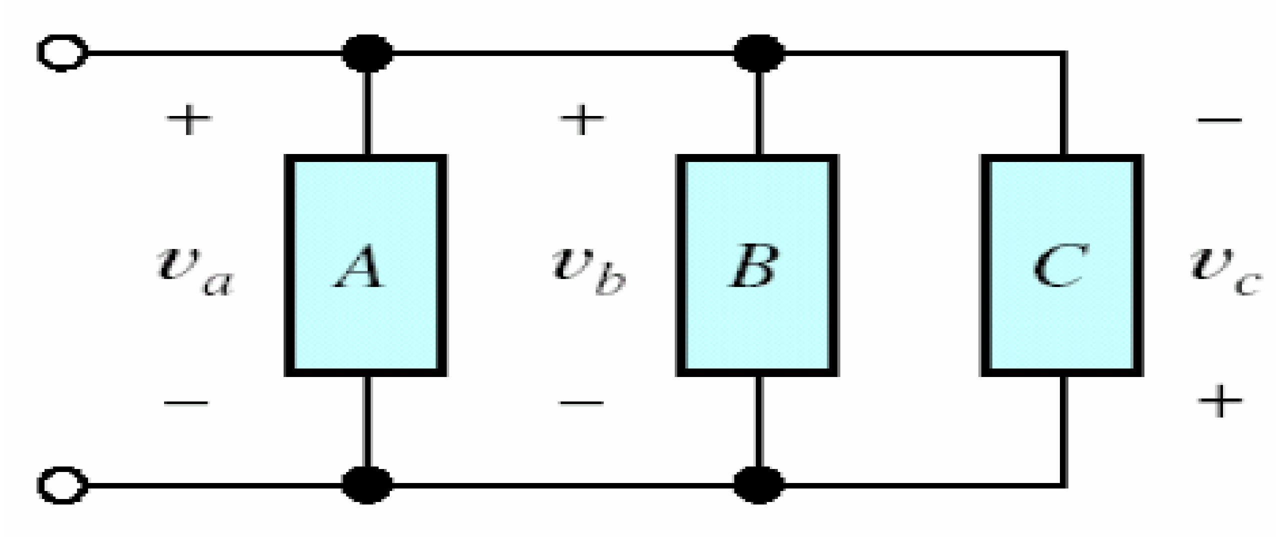
Two elements are connected in parallel if both ends of one element are connected directly to corresponding ends of the other



A and B are connected in parallel

D, E and F are connected in parallel

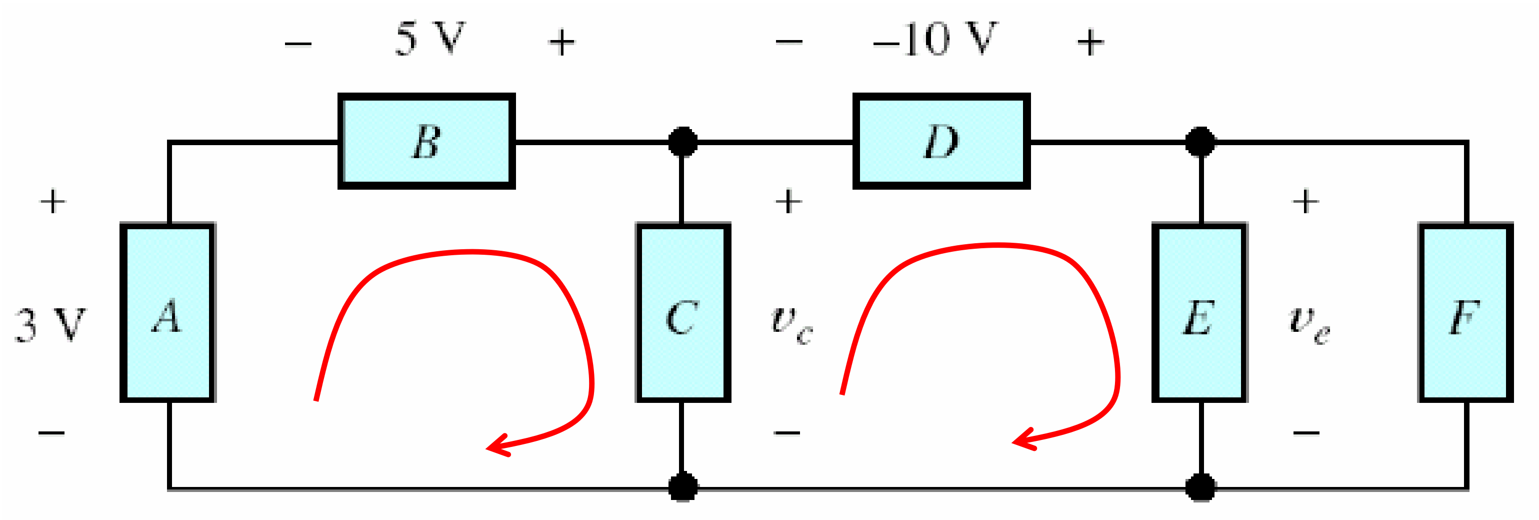
The voltage across parallel elements are equal (both magnitude and polarity)



$$v_a = v_b = -v_c$$

Example

Use KVL to find v_c and v_e

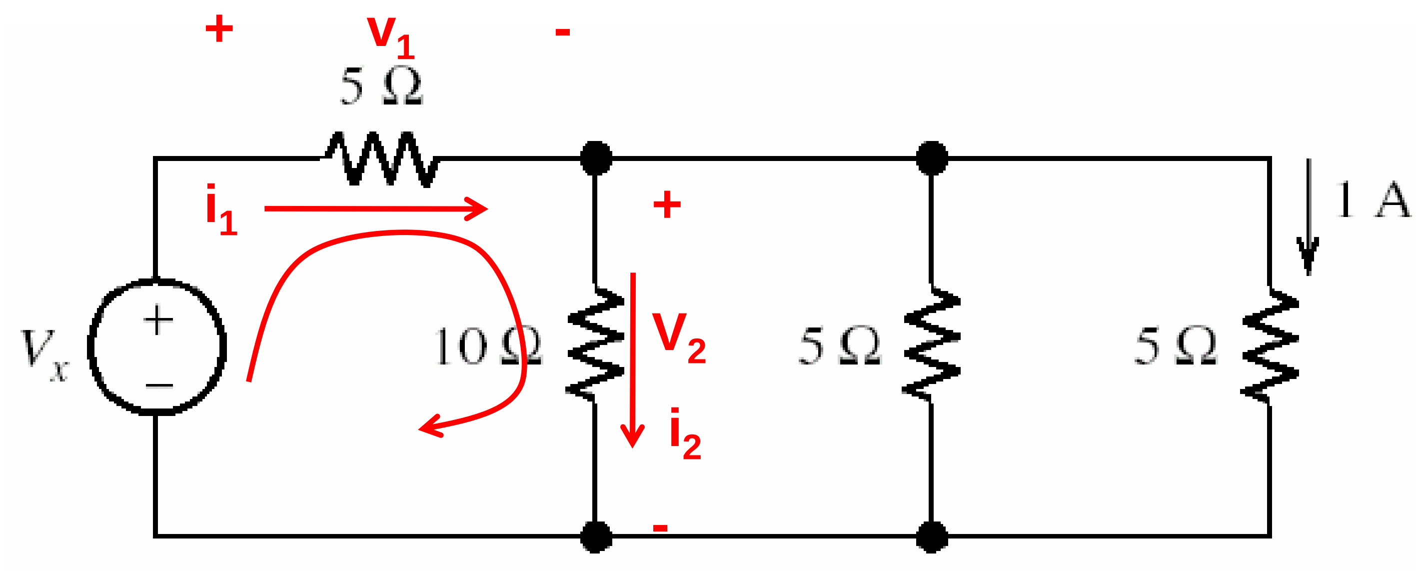


$$-3-5+v_c=0 \Rightarrow v_c=8V$$

$$-v_c-(-10)+v_e=0 \Rightarrow v_e=-2V$$

Use KVL , KCL and Ohm's law to solve the given problem

Find V_x



Step 1

$$-v_x + v_1 + v_2 = 0 \Rightarrow v_x = v_1 + v_2$$

KVL

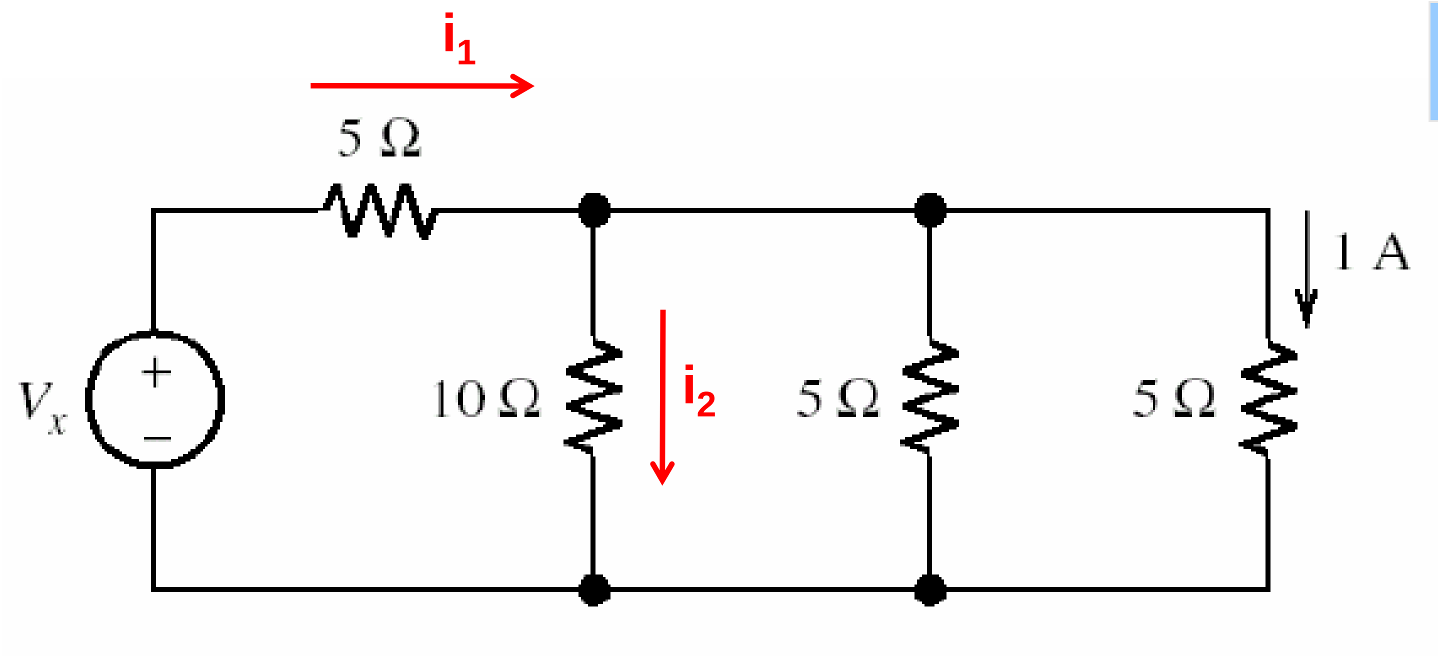
Step 2

$$v_1 = i_1 \times 5$$

$$v_2 = i_2 \times 10$$

Ohm's Law

Step 3: Find currents i_1 and i_2



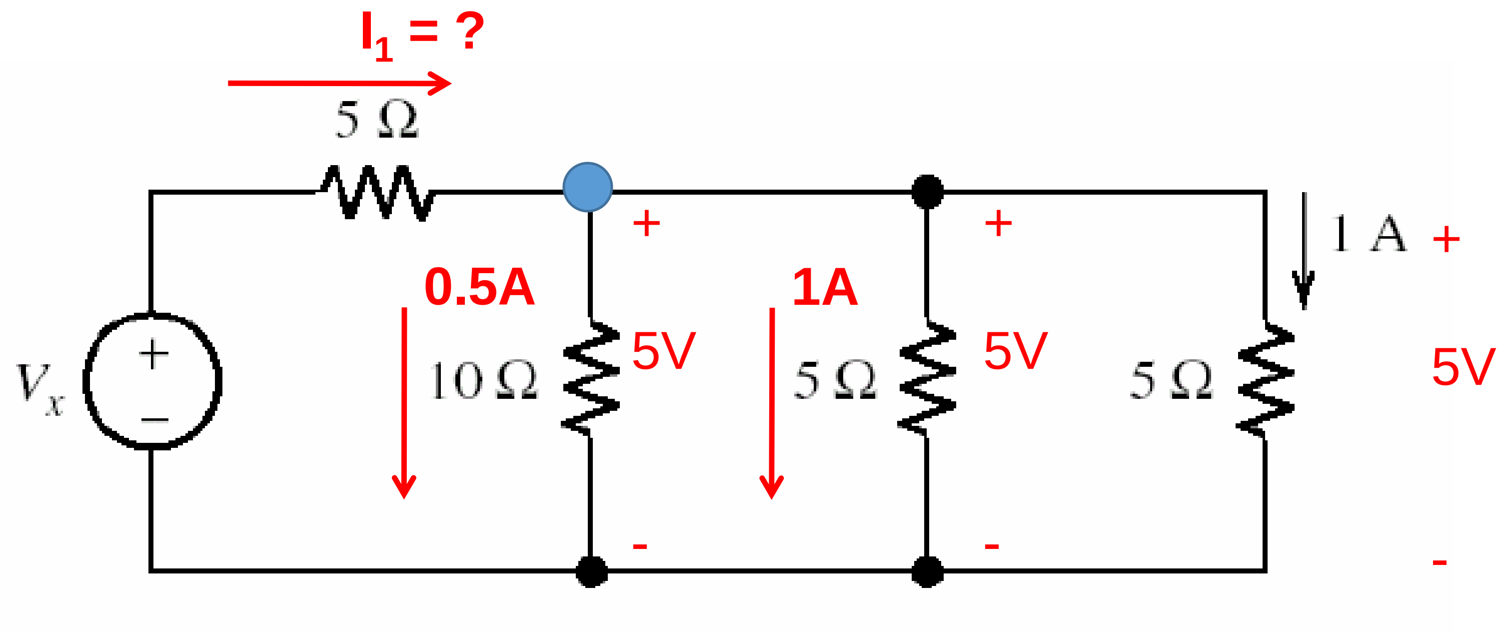
$$v_x = v_1 + v_2$$

$$v_1 = i_1 \times 5$$

$$v_2 = i_2 \times 10$$

$$v_x = (i_1 + 2 i_2) \times 5$$

Use ohm's law : v = I x R



Apply KCL at the indicated node

$$i_1 - 0.5 - 1 - 1 = 0 \Rightarrow i_1 = 2.5A$$

$$v_1 = i_1 \times 5 = 12.5V$$

$$v_x = v_1 + v_2 = 12.5 + 5 = 17.5V$$