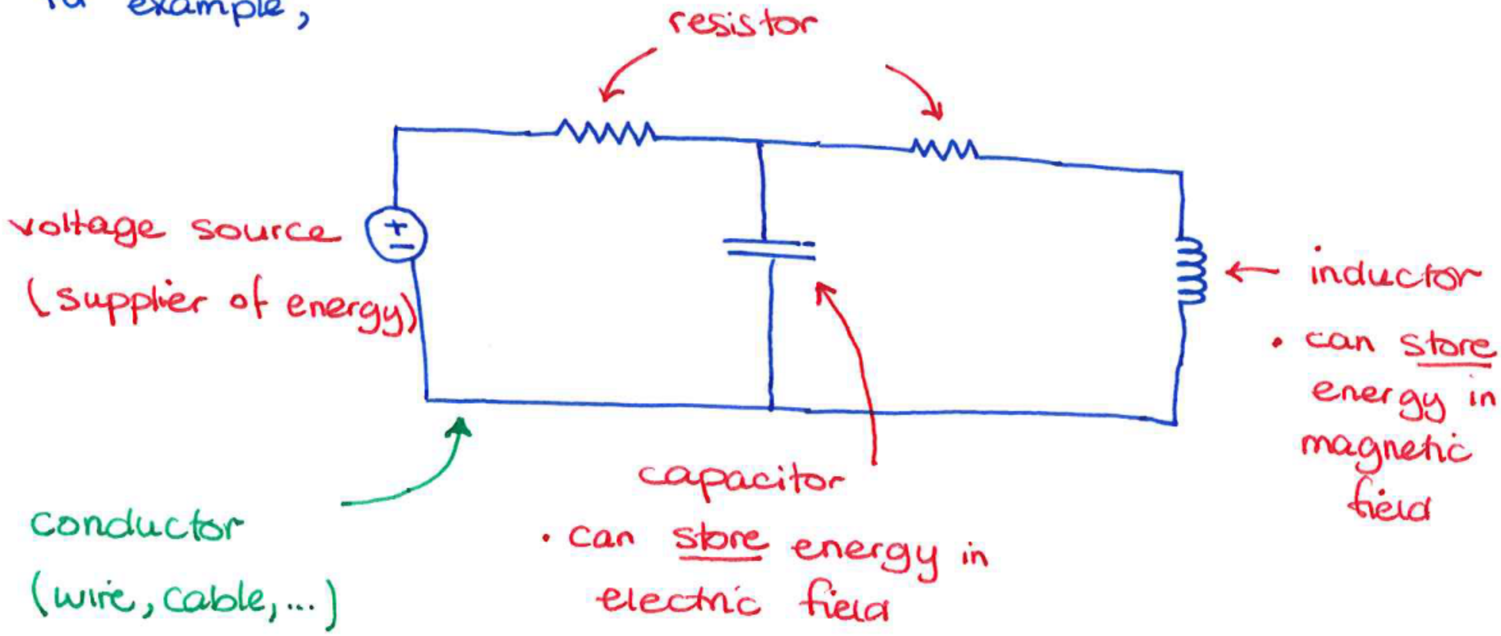
Electric circuit : Interconnection of circuit elements in a closed path by conductors

for example,



- The concept of electrical charge is the basis for describing all electrical phenomena.
  - charge exists in discrete quantities at integer multiples of 1.6×10^{-19} Coulomb (charge of an electron)
- When analyzing electric circuits, there are 2 fundamental electrical quantities : current & voltage

Electric Current : Rate of flow of electrical charge

$$i(t) = \frac{d\,q(t)}{dt}$$

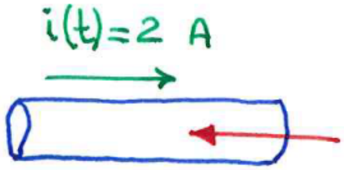
$i(t)$: current in Amperes (A)

$q(t)$: charge in Coulombs (C)

t : time in seconds

e.g. $1\,A = 1\,C/s$

· Note that $i(t)$ is a measure of equivalent positive charge flow. i.e.



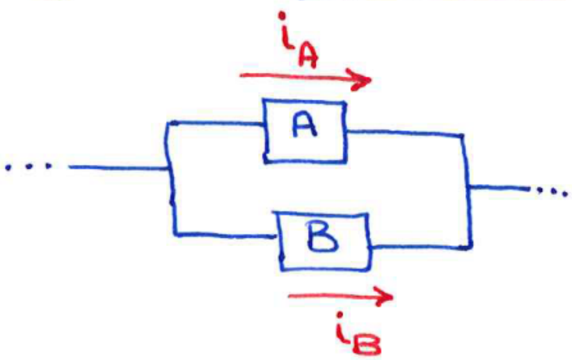
2 C/s of electrons

or 12.48×10^{18} electrons / sec

· Given $i(t)$, we can also find $q(t)$:

$$q(t) = \int_{t_0}^{t} i(t)\,dt + \underbrace{q(t_0)}_{\text{initial value at } t_0}$$

· We normally assign reference direction for current:



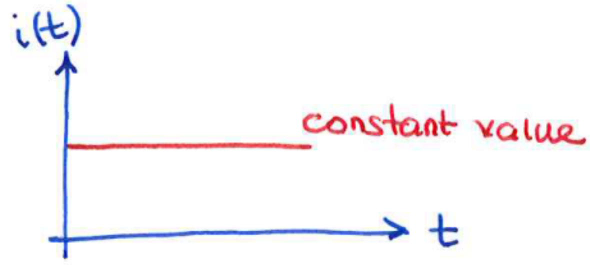
A, B could be any circuit element: source, resistor, etc.

– If current direction is not known, you can choose reference direction arbitrarily

· Actual direction will be indicated by the sign of i_A, i_B once the circuit is analyzed (solved).

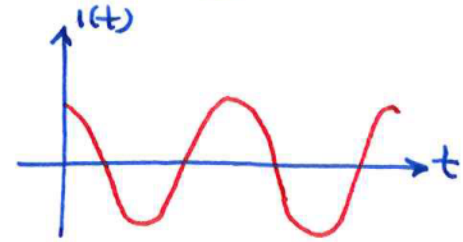
e.g. if we calculate $i_A = -5$A in the circuit above, then the actual current in A is 5A right to left.

- We can have Direct Current (DC) & Alternating Current (AC):



DC

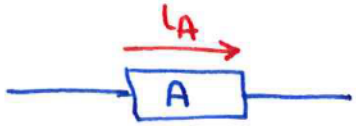
e.g. battery



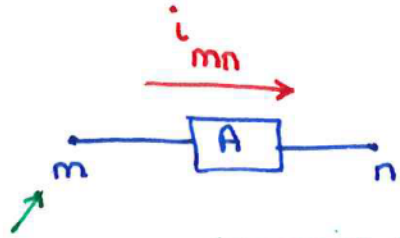
AC

e.g. house outlets

- Notation:

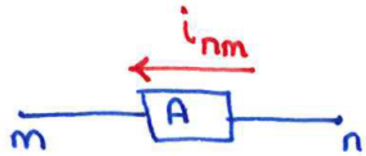


branch current



terminal or node

terminal reference



$$i_{mn} = -i_{nm}$$

Voltage: Energy transferred to/from a circuit element per unit of charge flowing through it. Also called potential difference.

$$v(t) = \frac{d\,w(t)}{d\,q(t)}$$

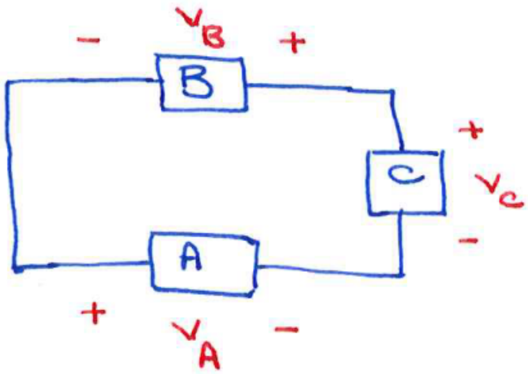
$v(t)$: Voltage in Volts (V)

$w(t)$: energy in Joules (J)

$q(t)$: charge in Coulombs (C)

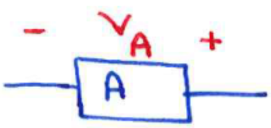
e.g. $1\,V = 1\,J/C$

- For analysis purposes, we can assign <u>reference polarities</u> (if they are not already given)

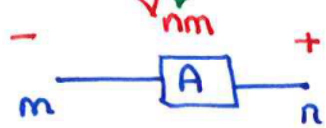


- can choose reference polarities arbitrarily
- If <u>actual</u> polarity is opposite, then value of v would be negative

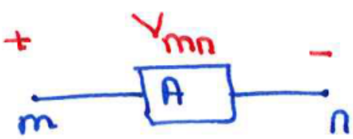
- Common notation:



first subscript on (+) terminal



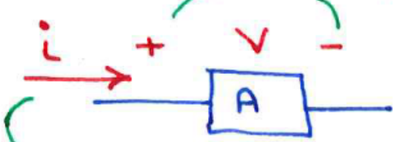
- v_A & v_{nm} will produce the same answer



$$v_{mn} = -v_{nm}$$

- <u>Actual</u> direction of current & <u>actual</u> voltage polarity indicate if an element is absorbing or supplying power:

actual polarity



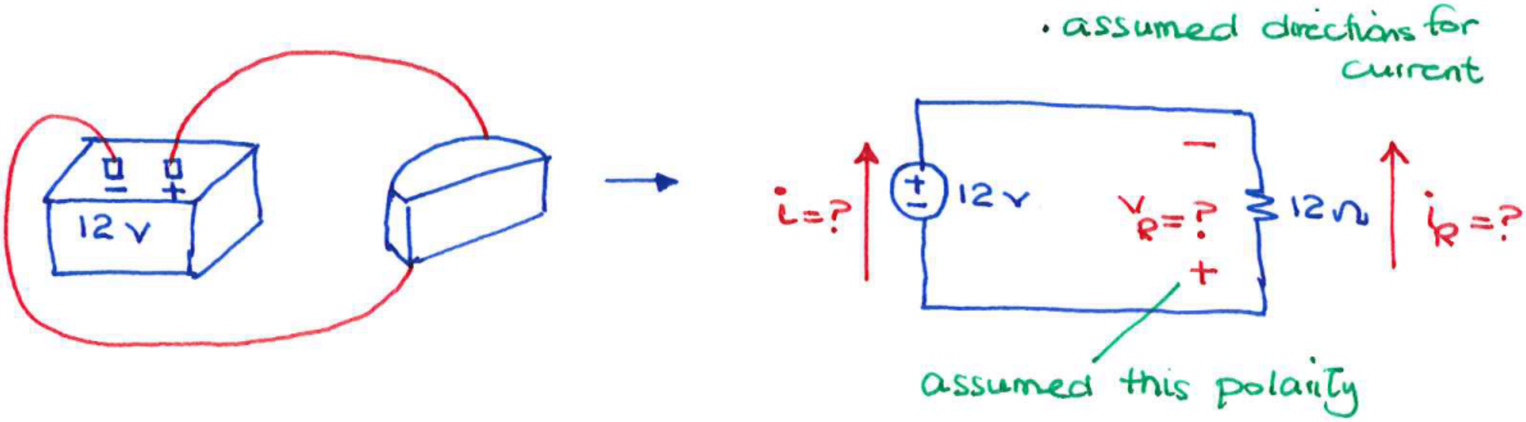
actual direction

power absorbed by A

power supplied by A

Yani's cheap plastic circuit example

Consider the circuit contacting the car battery and the headlights (Note: this is a simplified version of the actual circuit)



What do we know about this circuit (i.e. what is the voltage or current for any individual element)?

What we don't know:

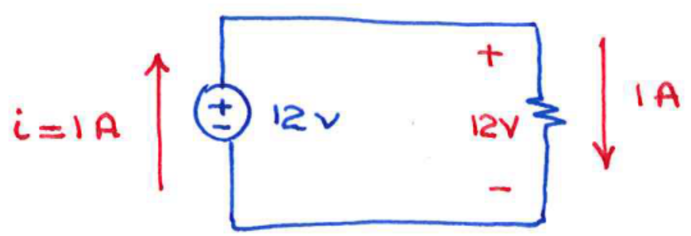
- Voltage across the lights
- Current through the lights
- Current through the battery

We can assume arbitrary directions/polarities for all of the above unknowns.

Why do we care what the voltages/currents are? Reasons can include, but are not limited to, the following:

- Lights require a certain voltage to operate properly. We can solve this circuit to find out if that voltage is provided.
- All the elements in this circuit (battery, light, and conductors) have a certain current rating (maximum amount of current they can handle before they start to overheat/melt/catch fire!) We need to make sure that the current is not exceeding that value.
- Once we know voltage and current for an element, we can calculate the power and energy it consumes/supplies.

After we solve this circuit (we haven't learned how to do that yet!), we will find the <u>actual</u> voltages and currents as follows:

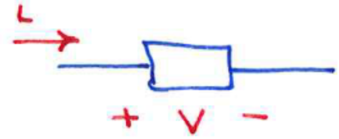


actual current in direction of voltage drop
∴ absorbs power

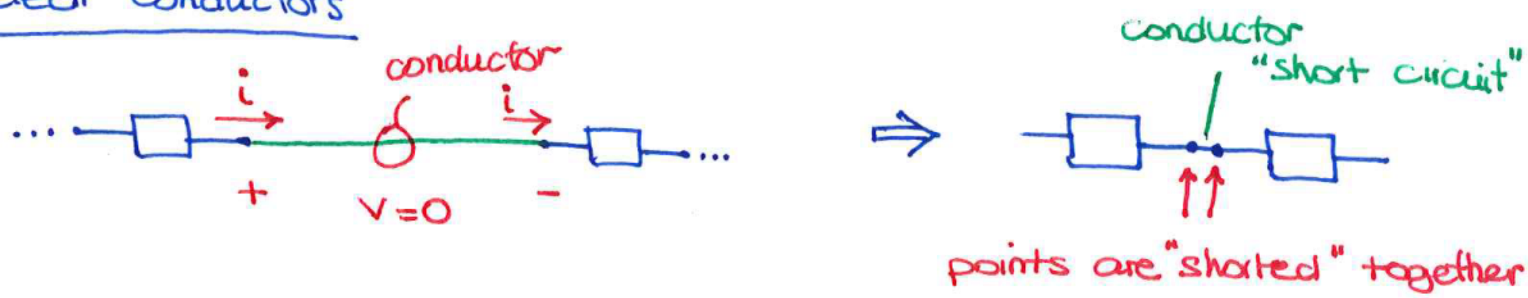
<u>actual</u> current in direction of voltage rise
∴ supplies power

Ideal Circuit Elements

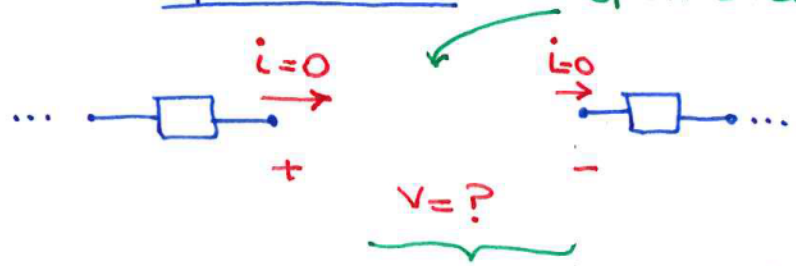
- Here we talk about conductors, sources, resistors. Later, we will bring in inductors, capacitors, op amps.
- All circuit elements are characterized by their <u>voltage-current relationships</u>.



Ideal Conductors



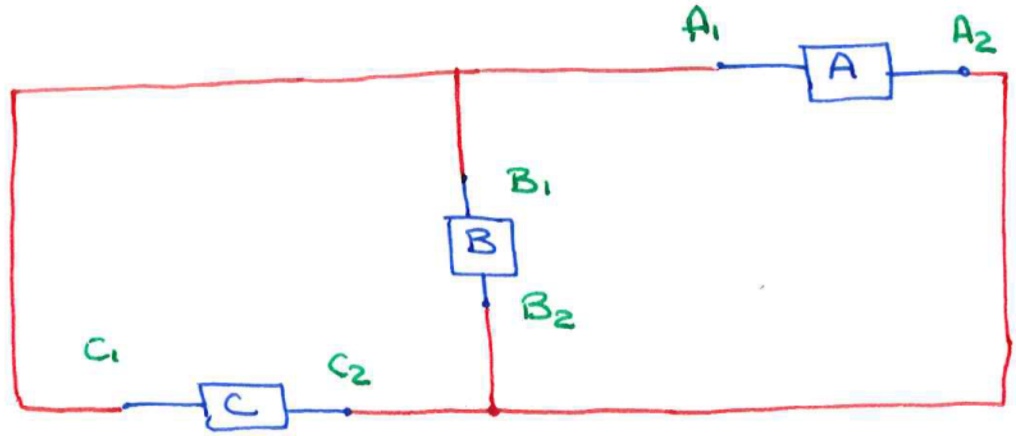
- The absence of a conductor between circuit elements is an <u>open circuit</u>: open circuit (a gap)



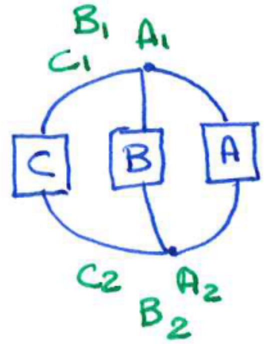
need to solve the circuit to find this

- Since all of our conductors are ideal, we can shorten or lengthen them as much as we like <u>as long as</u> the electrical connection between the circuit elements remain the same.

  For example, consider the following circuit where conductors connect terminals A_1, B_1, and C_1 together & terminals A_2, B_2, and C_2 together

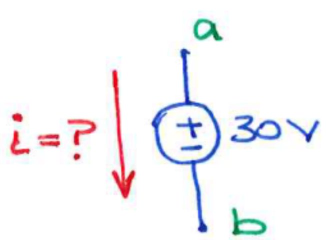


this circuit is electrically equivalent to:



Sources:

1) Independent Voltage Source



DC source

terminal a is higher in potential than terminal b by 30V.

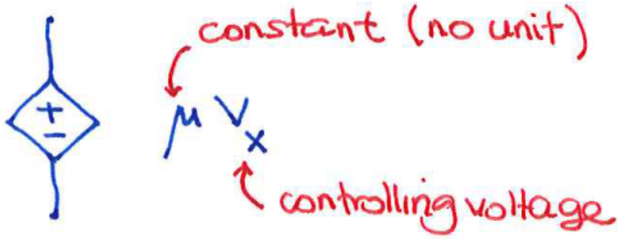
AC source

Properties:

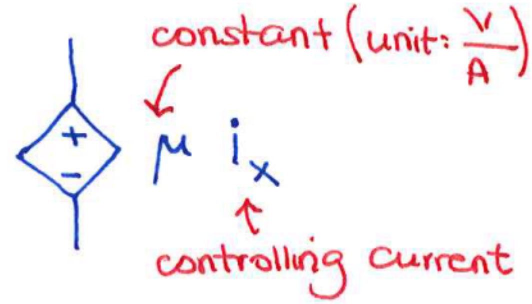
- Voltage (potential difference) is specified exactly. Not affected by any other circuit element.
- Current through the source depends on the circuit it is connected to. Need to solve the circuit to find this out.

2) Dependent Voltage Source

- Have the same properties as independent voltage sources except the value of voltage depends on either a voltage or current elsewhere in the circuit:



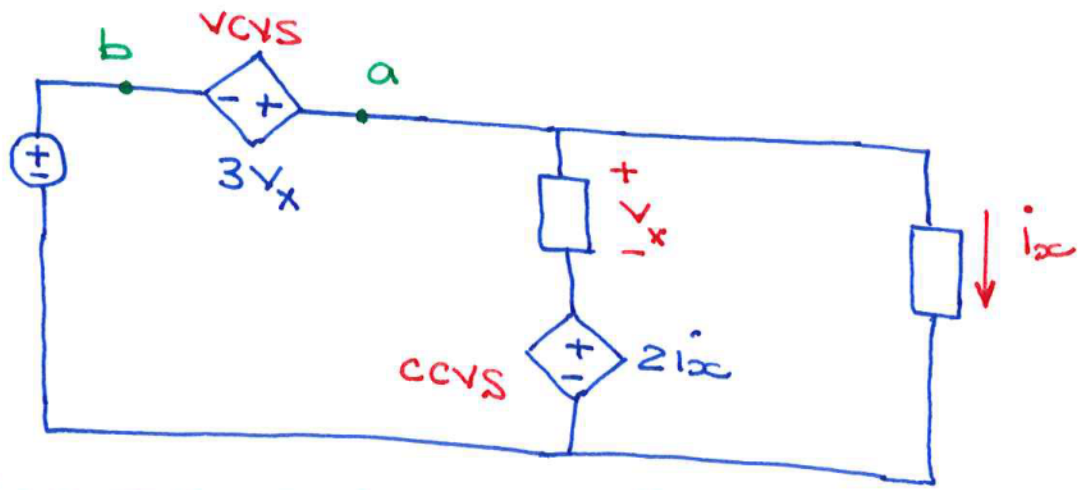
voltage-controlled voltage source (VCVS)



current-controlled voltage src. (CCVS)

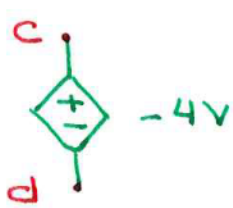
- These can be AC or DC.

- Ex: A circuit using dependent voltage sources:

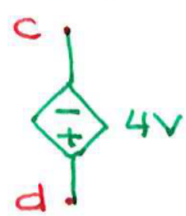


- If we calculate $V_x = 2\ V$, then VCVS is a 6V source. Point 'a' is higher in potential than point 'b' by 6V. Need to solve the circuit to find current through VCVS.

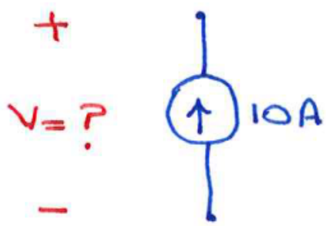
- If we calculate $i_x = -2A$, then CCVS is $-4V$:



which is the same as



3) Independent Current Source



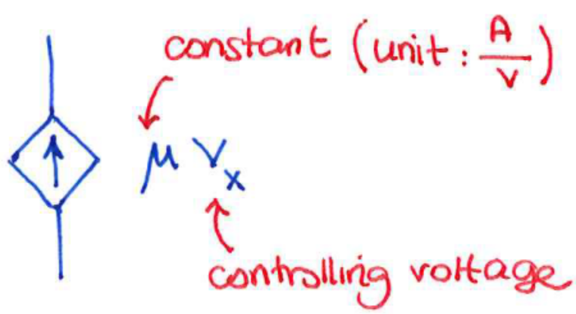
DC

AC

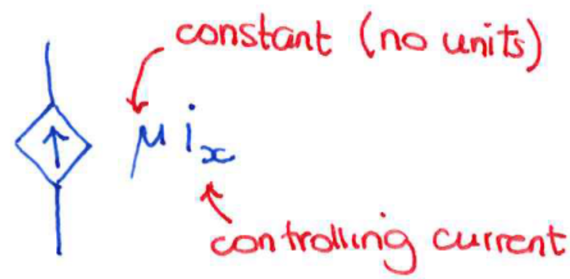
Properties:
- Current specified explicitly. Not affected by other circuit elements.
- Voltage across the source depends on the circuit it is connected to. Solve the circuit to find out.

4) Dependent Current Source

- Same properties as independent CS, except current depends on voltage or current elsewhere.



VCCS



CCCS

- For all dependent sources:
  - i_x or V_x are always labelled on the circuit, i.e. you do not need to assume their direction or polarity.
  - The given reference polarity or direction for V_x & i_x is not necessarily the <u>actual</u> polarity or direction of voltage or current for the controlling element.