Welcome to

ENEE2304
Circuit Analysis

Instructor
Dr. Hakam Shehadeh

Text Book: ***Electric Circuits, 10th Edition*** **by Nilsson/Riedel**

Reading Assignment: **Chapter 2 in** ***Electric Circuits, 10th Edition*** **by Nilsson**

Chapter 2: Circuit Elements

Several types of electrical devices are introduced in this chapter, including independent sources, dependent sources, and resistors.

Reading Assignment: Chapter 2 in *Electric Circuits, 9th Edition* by Nilsson

Chapter 2: Circuit Elements

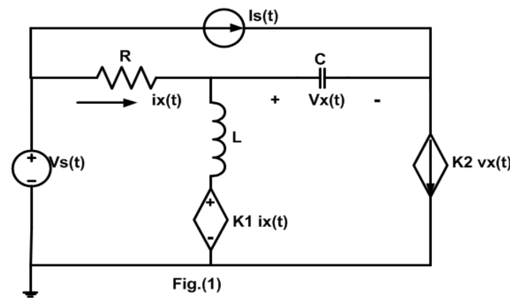


Fig.(1)

- Network : the interconnection of two or more simple circuit element is called electrical network.
- Circuit : if the network contains at least one closed path ,it is called electric circuit .
- Circuit analysis : given a circuit in which all the components are specified , **analysis involves finding such things as the voltage across some elements or the current through another**. **The solution is unique**.
- Circuit design involves determining the circuit configuration that will meet certain specifications . **The solution is not unique**.

Circuit Elements

1) Active element : capable of delivering power to some external elements (sources).

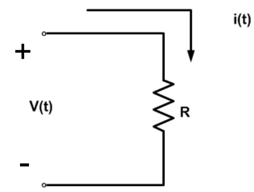
2)Passive element : capable only of receiving power (R,L,C,…).

Circuit element can be classified according to the relationship of the current through the element to the voltage a cross the element .

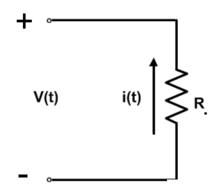
Chapter 2: Circuit Elements

1) Resistor

$$V(t) = R\,.\,i(t)$$
$$i(t) = \frac{1}{R}.V(t)$$
$$= G.V(t)$$



$$V(t) = -R.\ i(t)$$



- R is called the resistance of the the component and is measured in units of ohm (Ω)
- G is called the conductance of the component and is measured in units of Siemens (ʊ)

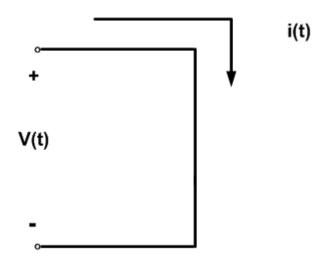
**** two special resistor values**

First : short circuit

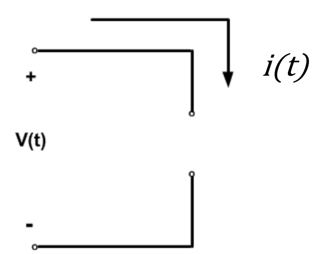
R=0 Ω

V(t)=0*V** ***i(t)= ???

G=∞ʊ



Second: Open Circuit



R=∞Ω

i(t)= 0 A ***V(t)=???***

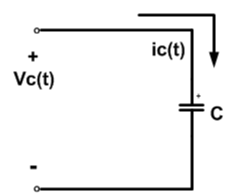
G= 0ʊ

Resistors and electric Power

Resistors are passive elements that can only absorb energy

$$P(t) = V(t).i(t)$$
$$V(t) = R.i(t)$$
$$P(t) = \frac{V^2(t)}{R}$$
$$P(t) = R.i^2(t)$$

2. Capacitors



$$V_C(t) = \frac{1}{C}\int_{-\infty}^{t} i_C(t)dt$$

$$V_C(t) = V_C(0^-) + \frac{1}{C}\int_{0^-}^{t} i_C(t)dt \quad \text{for } t \geq 0$$

$$i_C(t) = C\frac{dv_C(t)}{dt}$$

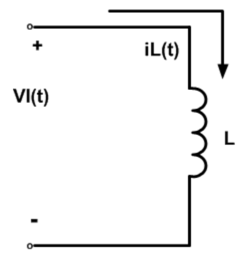
C is called the capacitance of the capacitor and is measured in units of farad (F)

3. Inductors

$$V_L(t) = L\frac{di_L(t)}{dt}$$

$$i_L(t) = i_L(0^-) + \frac{1}{L}\int_{0^-}^{t} V_L(t)dt \quad \text{for } t \geq 0$$

L is called the inductance of the coil and is measured in units of the henry (H)



Independent voltage source – A circuit element in which the voltage across its terminals is completely independent of the current through it .

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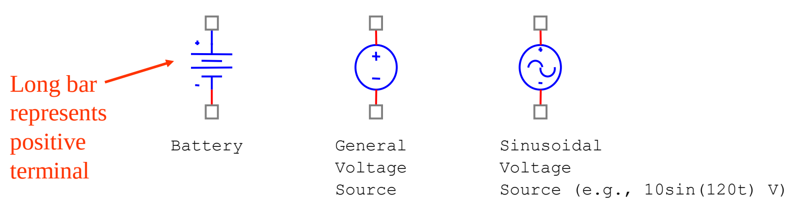
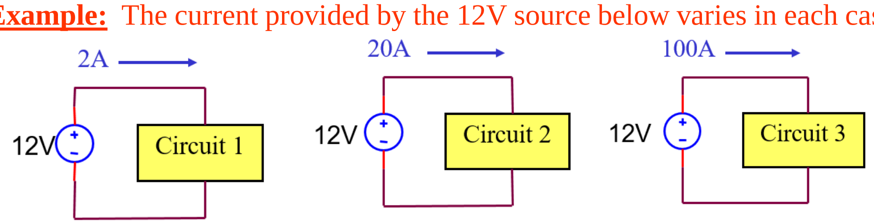
Symbols:



- The symbols shown above are from PSPICE. The boxes on the ends of the wires are simply for connecting wires or other components to the sources.
- Voltages sources have a specified voltage, but the current depends on the circuit and is determined through analysis.

Example: The current provided by the 12V source below varies in each case.

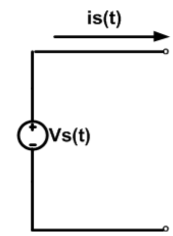


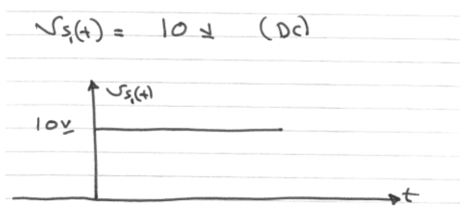
Voltage Source

$Vs1(t) = 10\ V\ (DC)$

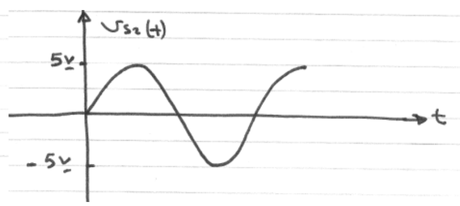
$Vs2(t) = 5\sin\omega t\ \ V\ (ac)$

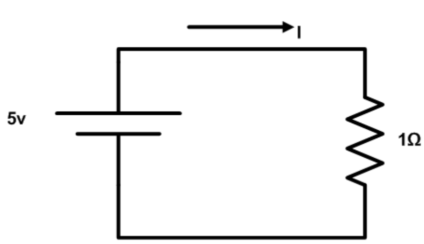
$Vs3(t) = 10\ e^{-t}\ V$

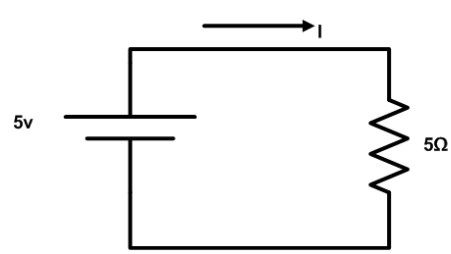




$Vs2(t) = 5\sin\omega t\ \ V\ (ac)$







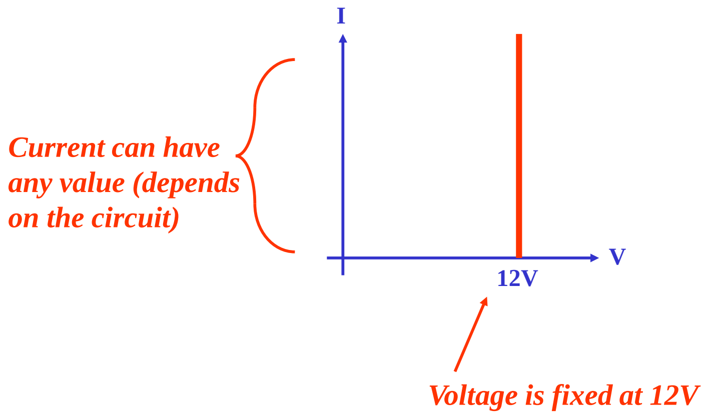
$$I = \frac{5v}{1\ \Omega} = 5A$$

$$I = \frac{5v}{5\Omega} = 1A$$

Independent voltage source characteristics

The "characteristics" of a device typically refers to a graph of I versus V which illustrates the behavior of the device.

The characteristics of an ideal independent 12 V voltage source are shown below.

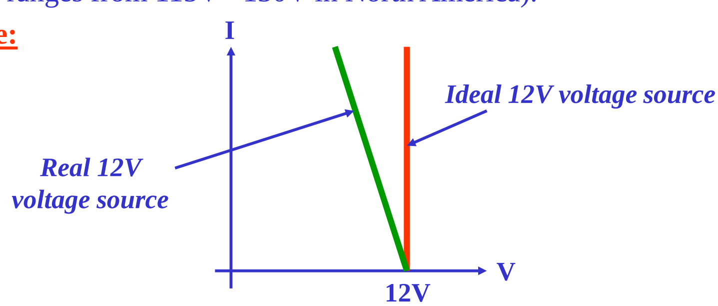


Real versus ideal independent voltage sources

The voltage delivered by an **real voltage source** (or practical voltage source) will typically drop as the current required by the source increases. For example:

- The 1.5V across a D-cell in a flashlight drops when the light is turned on.
- The 12V across a car battery drops when the car is started.
- The voltage from a power company drops during peak load hours (the voltage typically ranges from 115V - 130V in North America).

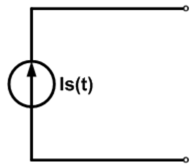
Example:



Note: Any voltage source shown in the text is assumed to be ideal.

Independent current source – A circuit element in which the current through it is completely independent of the voltage a cross its terminals. (This device is not as common in everyday use as the independent voltage source.)

Symbol:

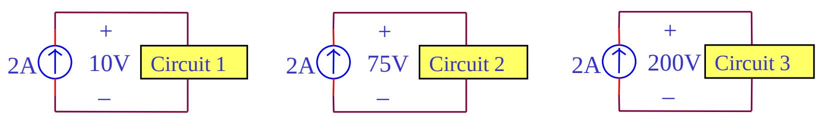


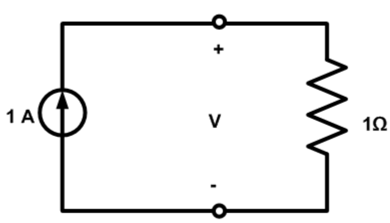
$$is(t) = 10\ \sin wt\ \ A$$

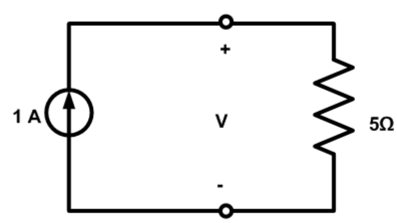
$$is(t) = \ 20\ A$$

- Current sources have a specified current, but the voltage depends on the circuit and is determined through analysis.

Example: The voltage provided by the 2A source below varies in each case.





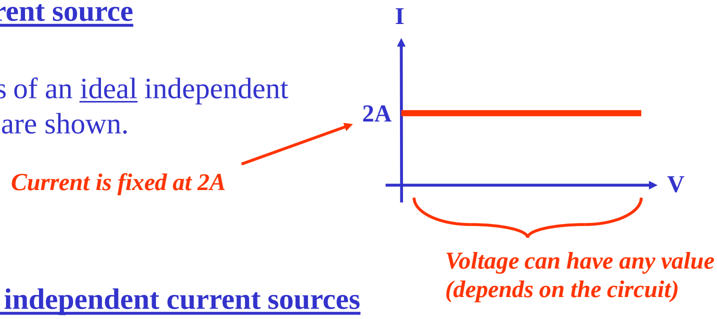


$$V\ = (1\ A\ ).\ (1\ ohm) = 1\ V$$

$$V\ = (1\ A\ ).\ (5\ ohm) = 5\ V$$

Independent current source characteristics

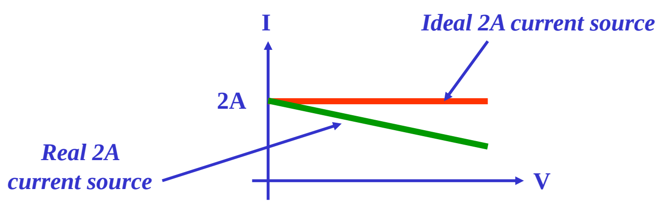
The characteristics of an ideal independent 2A current source are shown.



Real versus ideal independent current sources

The current delivered by an **real current source** (or practical current source) will typically drop as the voltage required by the source increases.

Example:

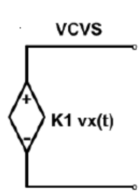


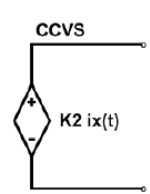
Note: Any current source shown in the text is assumed to be ideal.

Dependent Sources

- Are sources in which the source voltage (or current) depend upon a current or voltage else where in the circuit .

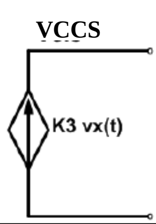
Voltage Controlled Voltage Source

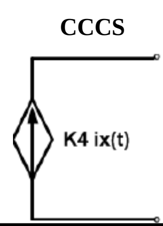




Current Controlled Voltage Source

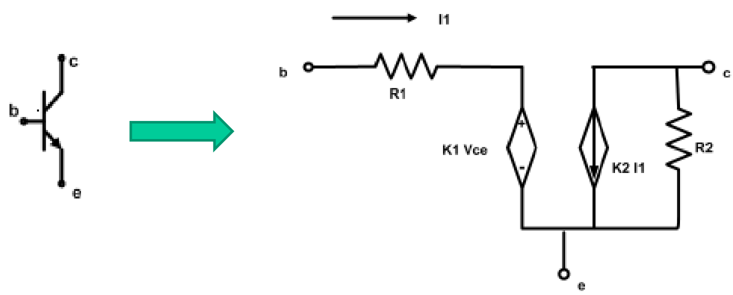
Voltage Controlled Current Source





Current Controlled Current Source

Transistor Model example



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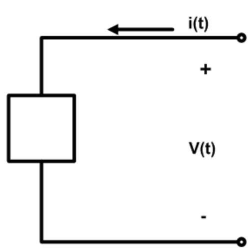
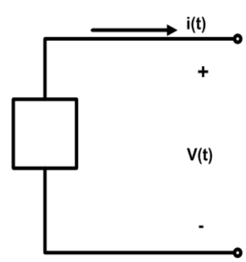
Power and Energy

$$p(t) = \frac{dw(t)}{dt}$$



$p(t) = +v(t)i(t)\ absorbing$



$p(t) = -v(t)i(t)\ supplying$

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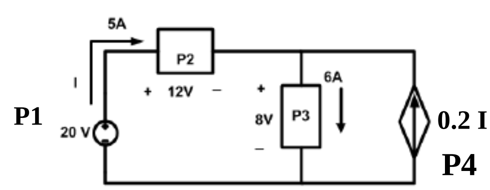
Conservation of Energy

- The law of conservation of energy must be obeyed in any electric circuit .
- The algebraic sum of power in a circuit at any instant of time ,must be zero.

$$\sum p(t) = 0$$

- Calculate power supplied or absorbed by each element



$$p1 = (20)(-5) = -100\ w \quad supplied\ power$$

$$p2 = (12)(5) \quad = 60w \quad absorbed\ power$$

$$p3 = (8)(+6) = 48w \quad absorbed\ power$$

$$p4 = (8)(-0.2 \times 5) = -8w \quad supplied\ power$$

$$p\ absorbed = p\ supplied$$

$$60 + 48 = 100 + 8$$

Voltage and Current Laws

- **Definitions:**
  - ➢Node : A point of connection of two or more circuit elements.
  - ➢Loop: Any closed path through the circuit in which no node is crossed more than once.
  - ➢Mesh : Any loop that doesn't contain within it another loop.

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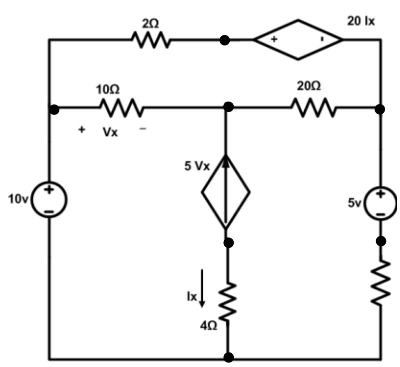

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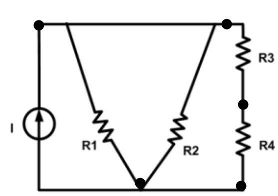
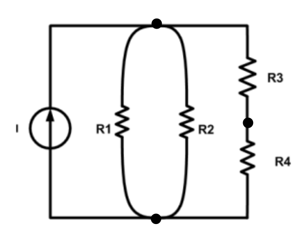
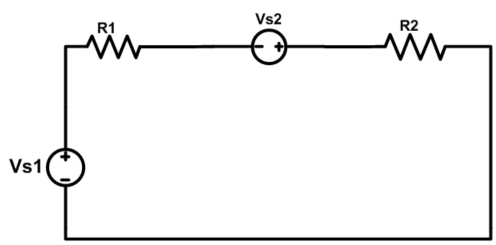




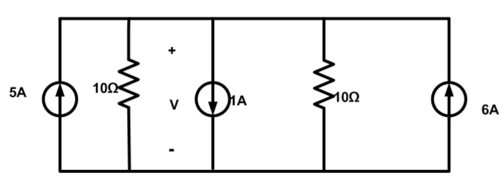
Series connections

- All of the elements in the circuit shown below carry the same current then said to be connected in series.



Parallel Connection

- Elements in a circuit having a common voltage a cross them are said to be connected in parallel.

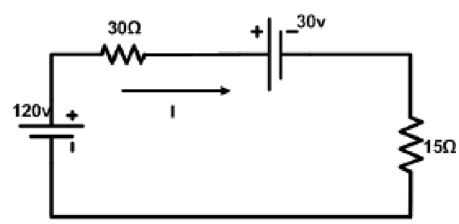


Two key laws for analyzing circuits:
Kirchhoff's Voltage Law (KVL)
Kirchhoff's Current Law (KCL)

Kirchhoff's Voltage Law (KVL)
Definition: "The algebraic sum of the voltages around any closed path equals zero."

Notes:
- Start at any point in a path
- Go around the loop in either direction until you return to the starting point
- Use a consistent sign convention

Analysis of a single- loop circuit



KVL

- 30 I + 30 + 15 I - 120=0 ➔
- 45 I=90 ➔ I=2 A
- V(30Ω) = (30 Ω).(2 A) = 60 V
- V(15Ω) = (15 Ω) (2 A)= 30 V

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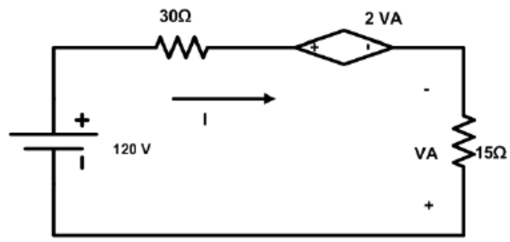
Analysis of a circuit containing a dependent source .



- Find I?

and calculate power absorbed by each circuit element

$30I + 2V_A + 15I - 120 = 0$

➔ $V_A = -15\,I$

➔ $I = 120/15 = 8A$

➔ $V_A = -120\ V$

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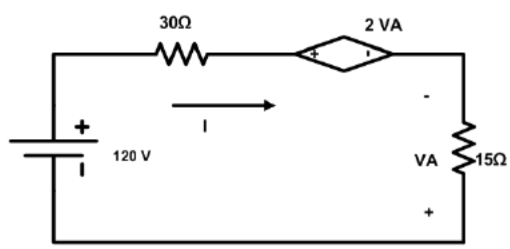
Analysis of a circuit containing a dependent source



- Find I?

and calculate power absorbed by each circuit element

$I = 120/15 = 8A$

- Answers:
- P(120v) = -960 W
- $P(2V_A)$= - 1920 W
- P(30Ω) = 1920 W
- P(15Ω) = 960 W

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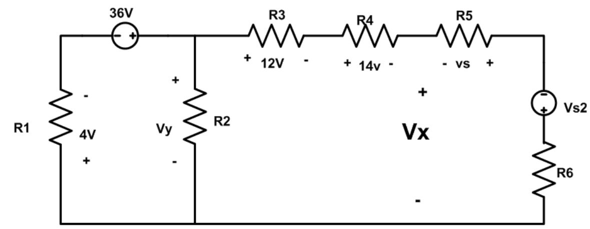
Applying KVL



- Find Vx and Vy
- KVL for 1-st loop: 4 – 36 + Vy=0

➔ Vy = 36 - 4 = 32 V

- KVL for second loop: -Vy + 12 + 14 +Vx=0

➔ Vx= -14-12+32 =6 V

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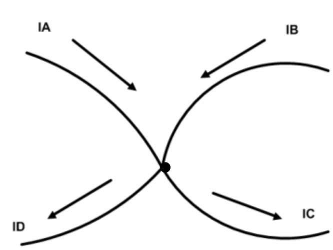
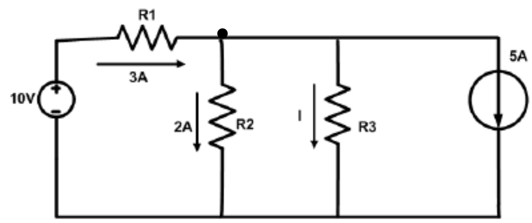
Kirchhoff's current law : KCL

- KCL : the algebraic sum of the current entering any node is zero
- $I_A + I_B - I_C - I_D = 0$
- KCL: Alternative form
- Sum of Currents In= Sum of Currents out
- $I_A + I_B = I_C + I_D$



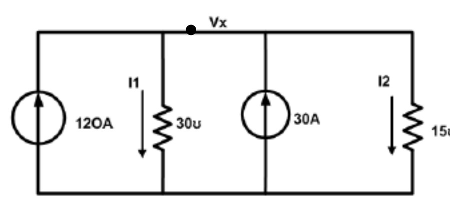
KCL Application



- Find I?
- KCL :
- 3 = 2+ I + 5

➔ I = -4A

Single node-pair circuit



- Find Vx?
- Remember I = G . V
- KCL : 120+30 = I1 +I2

  120+30 = 30Vx +15Vx

➔ Vx =3.33 V

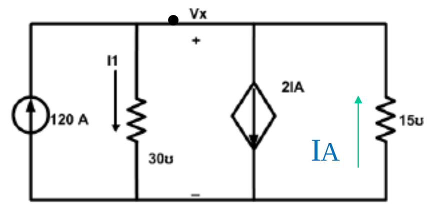
- I(30ʊ)= 100 A
- I(15 ʊ) =50 A

Analysis of circuit containing dependent sources

- Find Vx

KCL ;

- $120 \ +I_A \ = I_1 + 2\,I_A$
- $I_A \ = -\,15Vx$
- $I_1 = 30Vx$
- $Vx = 8$ V



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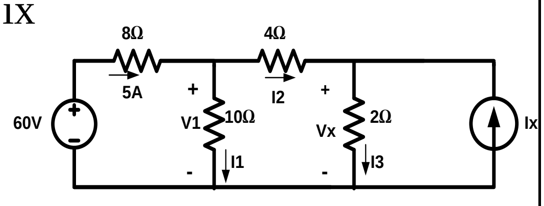
Applying KVL and KCL

- Solve for Vx and ix
- -60+(5A.)(8 Ω)+V1 =0

□ ➔ V1=60–40=20 V

- ➔ I1=20/10=2 A
- ➔ I2 =5–2= 3A



- Also I2=(V1–Vx)/4 =3A ➔ Vx=20-12= 8V
- I3=8/2=4 A

□ ➔ix=I3-I2 = 4-3 =1 A

- Answer : Vx= 8v and i_x=1A

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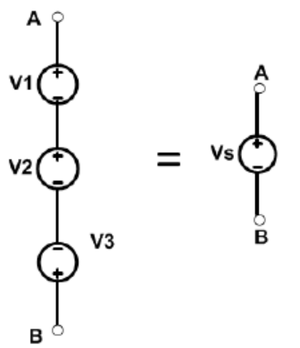
Series and parallel sources

- Voltage sources connected in series can be combined into an Equivalent source :



$$Vs = V_1 + V_2 - V_3$$

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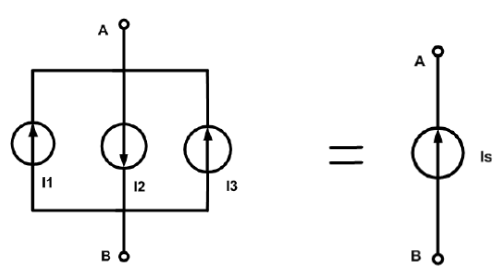
- Current sources connected in parallel can be combined in to an equivalent current source :



$$I_S = I_1 - I_2 + I_3$$

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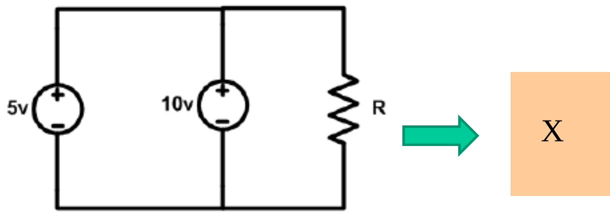
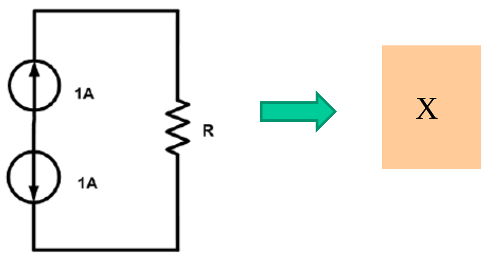
Impossible Circuit Configurations





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- Extra slides

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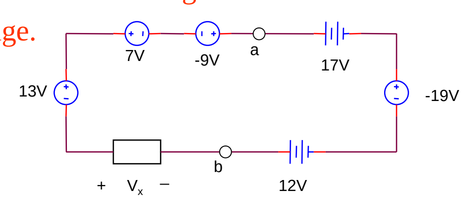
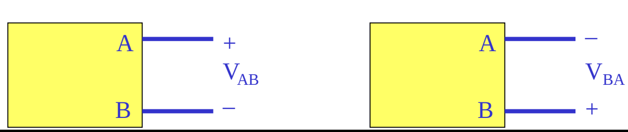
Example: Use KVL around the circuit below to find the voltage V_x. Discuss the difference in a sign due to convention and a sign due to the value of the voltage.



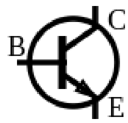
Two-subscript notation: Generally the polarity must be indicated with a voltage for it to be clearly defined. Another way to specify the polarity is to add subscripts indicating the location of the positive and negative terminals. For example:

V_{AB} = the voltage from A to B with the positive terminal at A

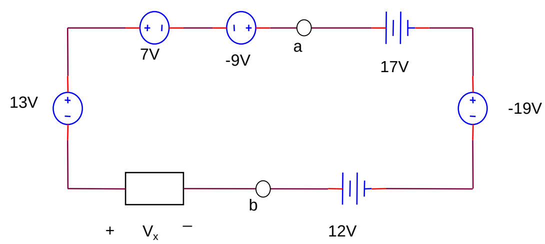
V_{BA} = the voltage from A to B with the positive terminal at B (Note that $V_{AB} = -V_{BA}$)



Example: Illustrate how two-subscript voltages are used with BJT's. Label V_{CE}, V_{BE}, and V_{CB} and use KVL to show a relationship between the voltages.



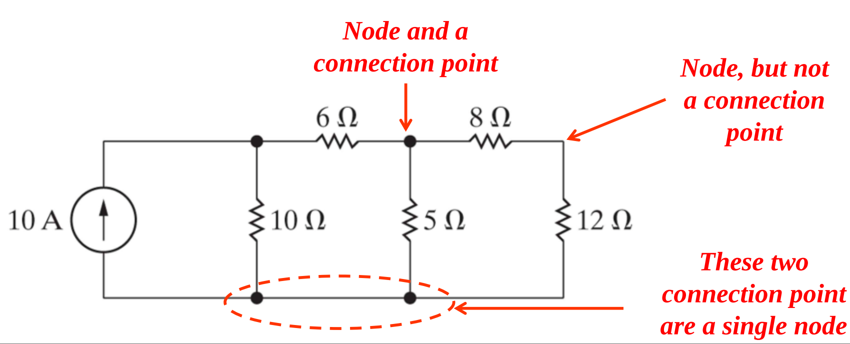
Example: Use KVL to find V_{ab} in the previous example. Recall that V_x = ______. Repeat using an alternate path for KVL.



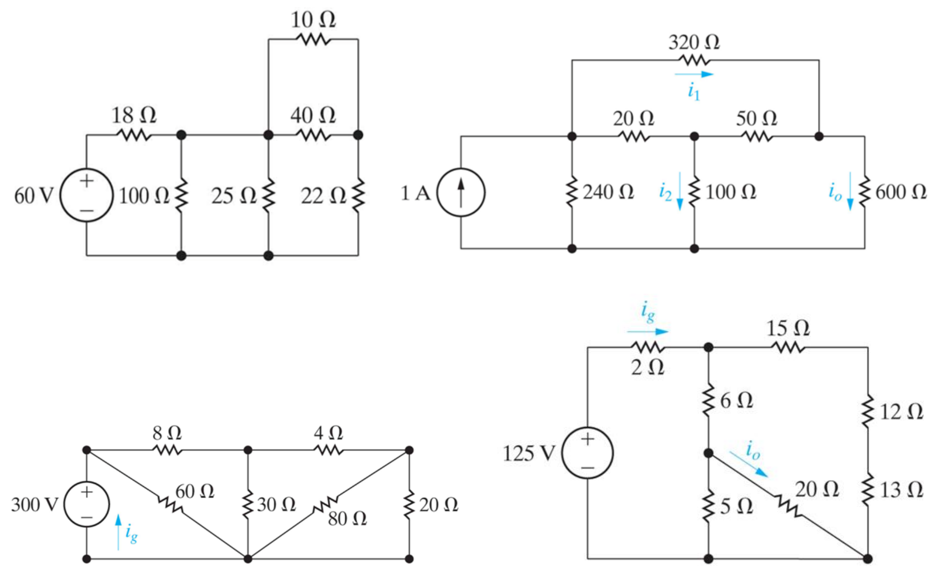
Kirchhoff's Voltage Law can be used to show an important law about parallel elements. Definitions for nodes and parallel elements are first introduced.

Node: A node is a junction in a circuit where two or more elements have a common connection. Additionally, there can never be two nodes connected by a wire (this would form a single node).

Note: Nodes are sometimes confused with connection points (or solder points). For example, the text typically uses solid circles (dots) to indicate connection points where three or more elements connect. These points may or may not be nodes.



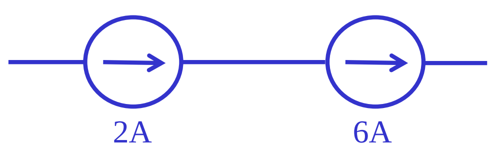
Example: How many nodes are in each circuit below? Label them.



Combining current sources (continued)

Key point: Current sources should not be placed in series (unless they have the same current).

Example: This is an improper connection. What law is violated here?

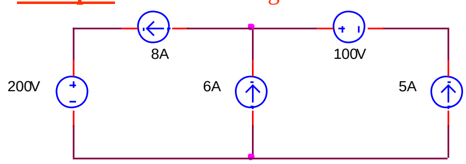


Practical exception: Current sources of the same value could be placed in series to increase the total voltage capability. For example, suppose that two 10A current sources each have V_{max} = 100V and they are placed in series. Illustrate.

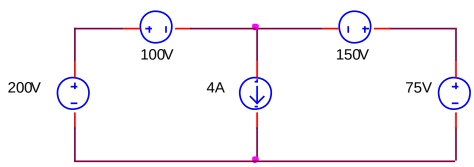
Valid versus invalid circuits

The text makes a point that all circuits must always satisfy KVL and KCL. A circuit that does not satisfy KVL or KCL is invalid and would be impossible to construct (or the circuit or equipment might be damaged). A few initial problems in the text ask is a circuit is valid. To test this, simply check KVL around various paths and KCL at various nodes to insure that no invalid equations occur.

Example: Is the following circuit valid?

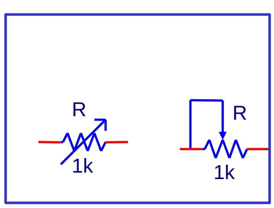


Example: Is the following circuit valid?



Variable resistors: Two names are used for variable resistors:

- potentiometer - Most common name (discuss other uses)
- rheostat



Symbols

12T

12T

15T

1T

1T

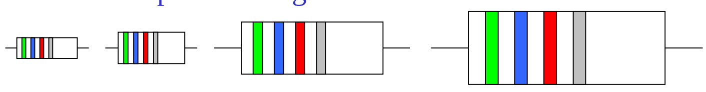
10T

Examples: Pass around examples of potentiometers.
¾ turn (1T) and 15T turn potentiometers.

Reference for images:
www.jameco.com

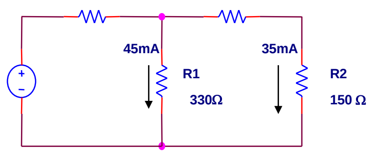
Power ratings for resistors: Resistors dissipate energy by giving off heat and/or light. Power ratings are related to the physical size of a resistor and to the type of material from which it is made.

Carbon resistors are often color coded (with the value of resistance) and their size is related to their power rating.



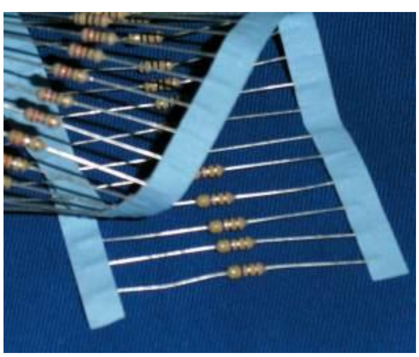
¼ W ½ W 1 W 2 W

Example: An engineer designs a circuit with the values shown below. If the circuit is to be built in lab, what are the minimum power ratings that should be used for resistors R1 and R2?



Demonstration – Pass around other types of resistors and discuss power ratings.

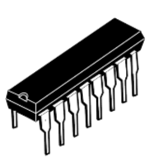
Examples of resistors:

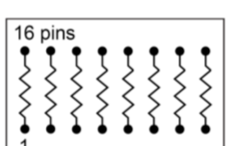


Carbon Resistors
Ref: www.wikipedia.com

Carbon Resistors
Ref: www.wikipedia.com

7W Ceramic Resistor
Ref: www.rapidonline.com





DIP Resistors Ref: www.jameco.com

Wirewound Resistor
Ref: www.newark.com