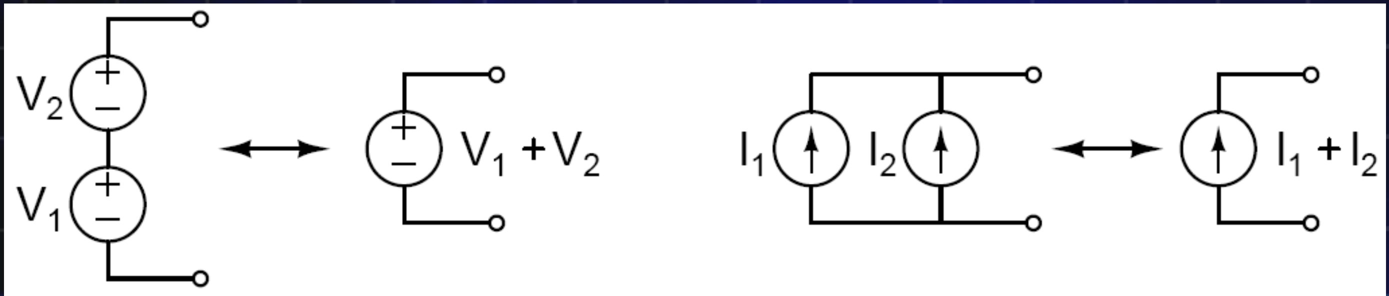
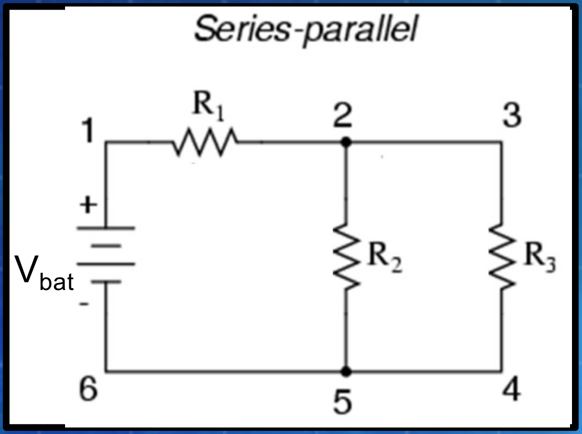
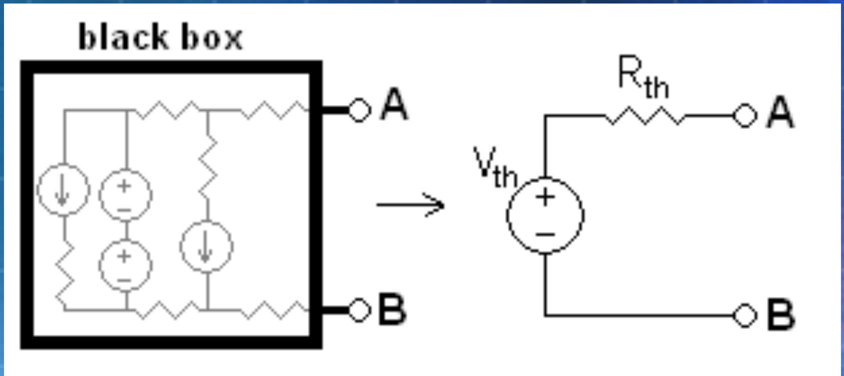






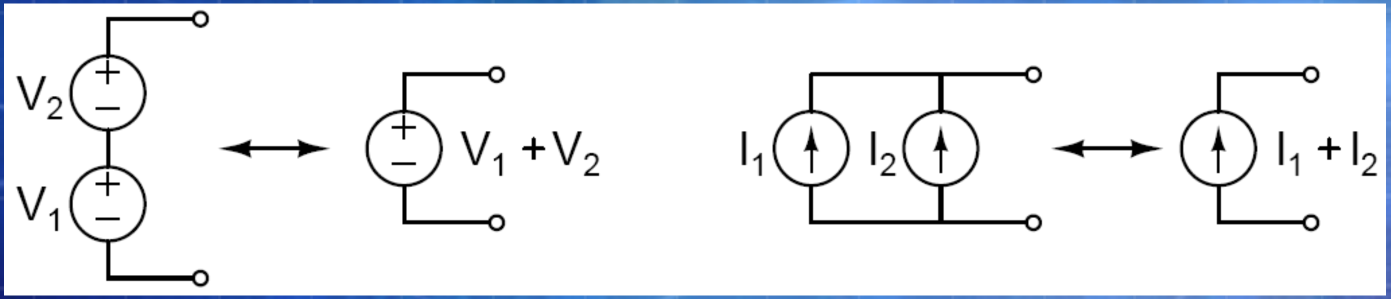
Circuit Lab

Practice #10—Kirchhoff's Voltage/Current Laws, Wheatstone Bridges, Thévenin's Theorem, and Norton's Theorem

Mr. Burleson
geaux15@hotmail.com

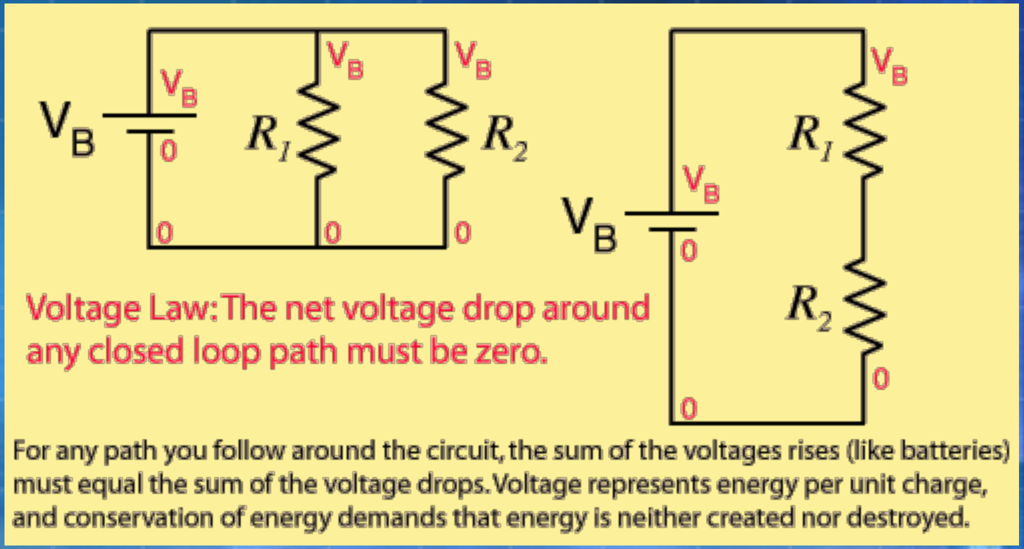
Multiple Sources

- Sometimes a circuit has more than one source
- <u>Voltage Sources</u> should be added in <u>series</u>
- <u>Current Sources</u> should be added in <u>parallel</u>
- You shouldn't put voltage sources in parallel or current sources in series, as it can create a situation that violates circuit rules.



Kirchhoff's Voltage Law (KCL)
(Division C Only)

- The directed sum of the electrical potential differences (voltage) around any closed network is zero
- or: the sum of the voltage in any closed loop is equivalent to the sum of the potential drops in that loop

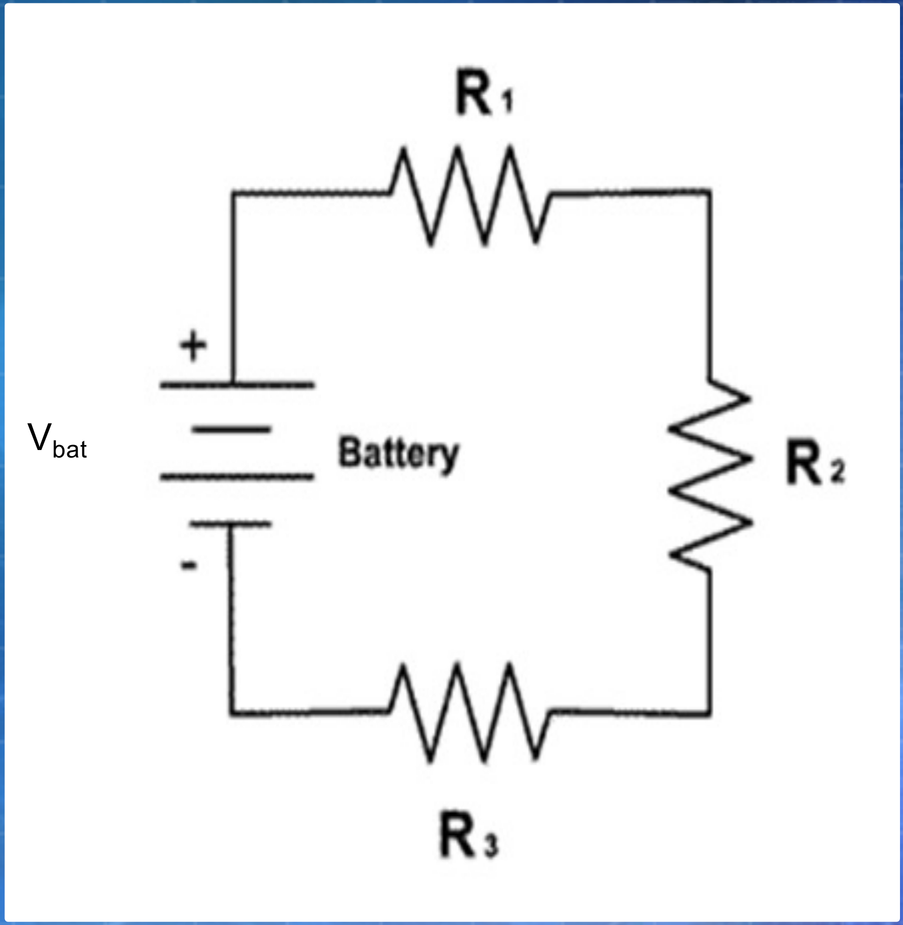


KVL Examples

- $V_{bat} = 9V$
- $V_{R1} = V_{R2} = 3V$
- What is V_{R3}

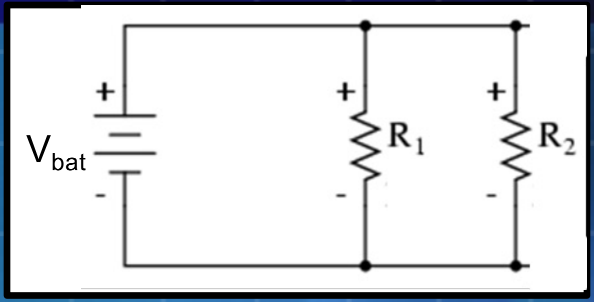
- $V_{bat} = 12V$
- $V_{R1} = 5V$, $V_{R2} = 3V$
- What is V_{R3}

- $V_{bat} = 15V$
- $V_{R1} = 7V$, $V_{R2} = 8V$
- What is V_{R3}

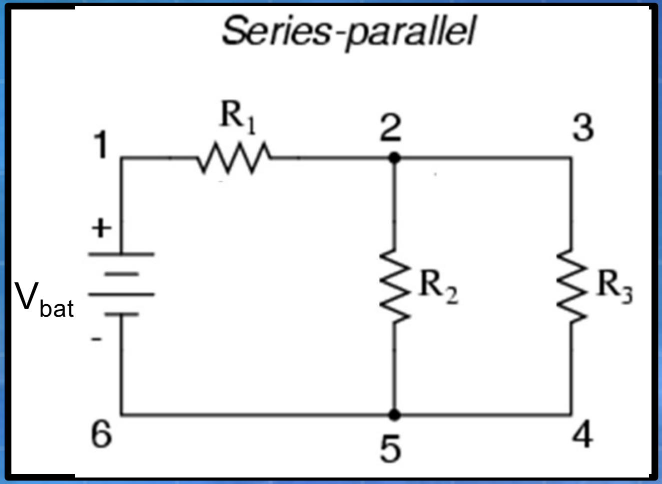


More KVL Examples

- $V_{bat} = 9V$
- What is V_{R1}?
- What is V_{R2}?



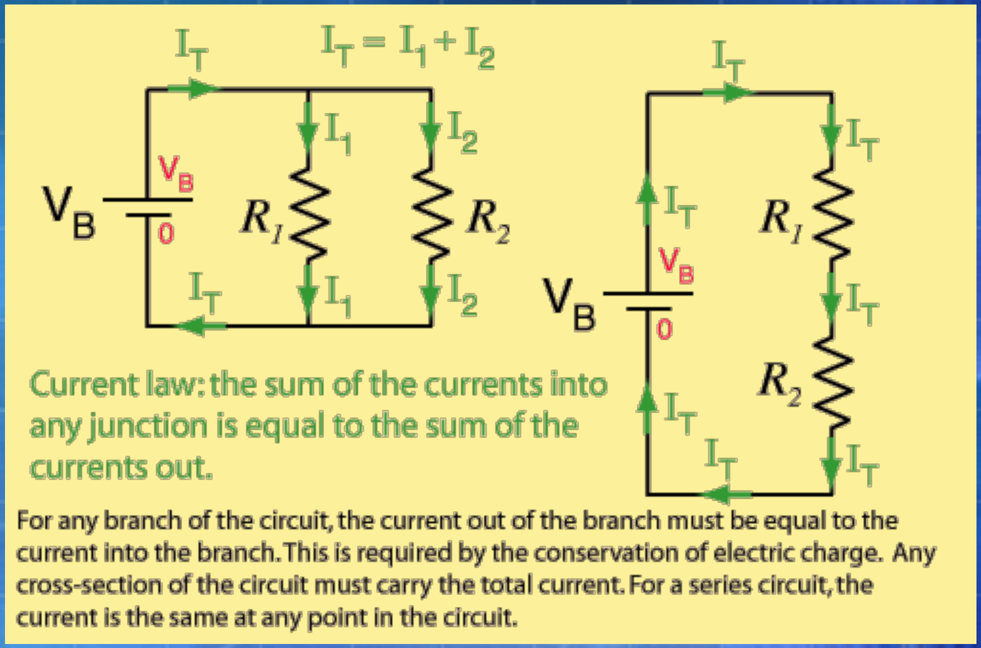
- $V_{bat} = 9V$
- $V_{R1} = = 3V$
- What is V_{R3} and V_{R2}



- $V_{bat} = 12V$
- $V_{R2} = = 3V$
- What is V_{R1} and V_{R3}

Kirchhoff's Current Law (KCL)
(Division C Only)

- At any node (junction) in an electrical circuit, the sum of currents flowing into that node is equal to the sum of currents flowing out of that node
- or: The algebraic sum of currents in a network of conductors meeting at a point is zero.
- or: All current into a node equals all current out!

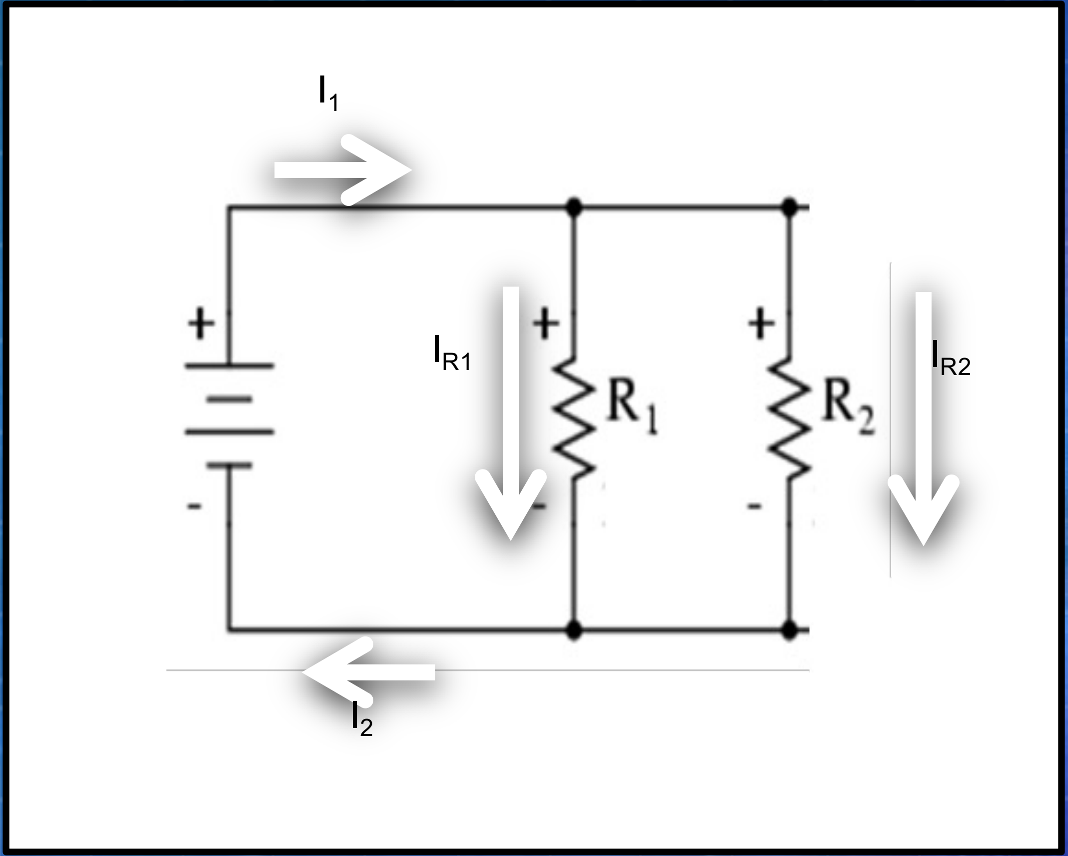


KCL Examples

- $I_1 = 9A$
- $I_{R1} = 3A$
- What is I_{R2} and I_2

- $I_1 = 9A$
- $I_{R1} = 6A$
- What is I_{R2} and I_2

- $I_1 = 10A$
- $I_{R1} = 4A$
- What is I_{R2} and I_2



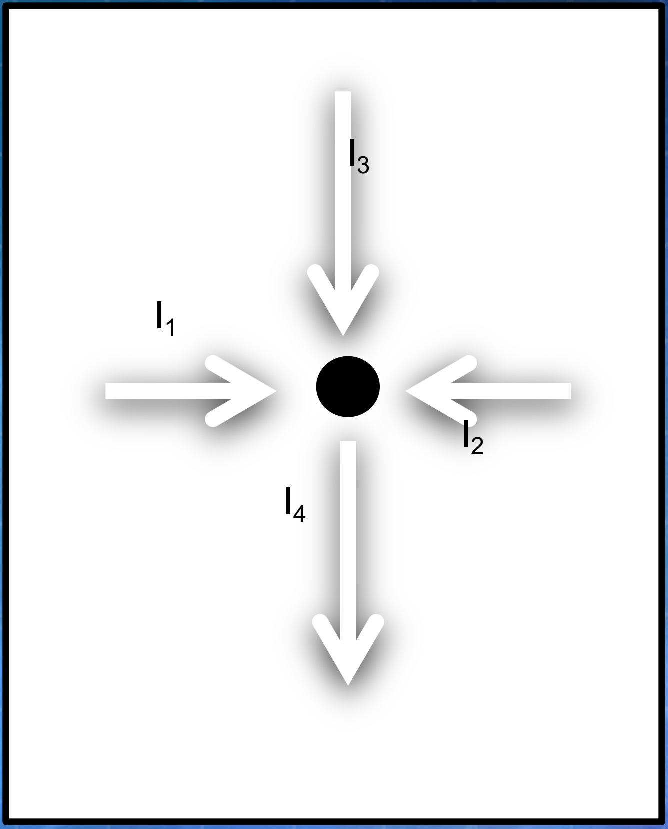
More KCL Examples

- $I_1 = 9A$, $I_2 = 9A$, $I_3 = 9A$
- What is I_4

- $I_1 = 5A$, $I_2 = 4A$, $I_4 = 3A$
- What is I_3

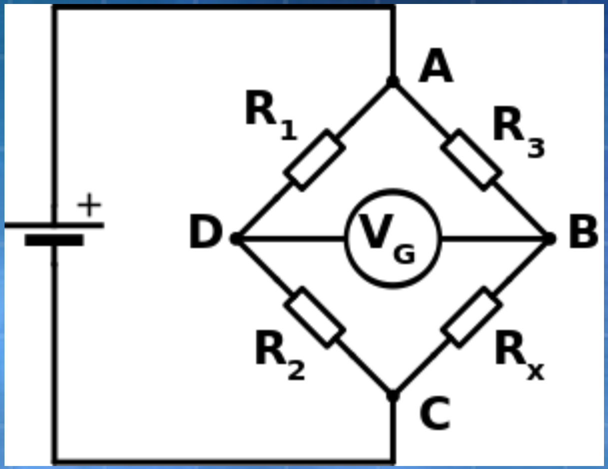
- $I_1 = 9A$, $I_2 = -9A$, $I_3 = 7A$
- What is I_4

- $I_1 = 2A$, $I_4 = 9A$, $I_3 = -9A$
- What is I_2



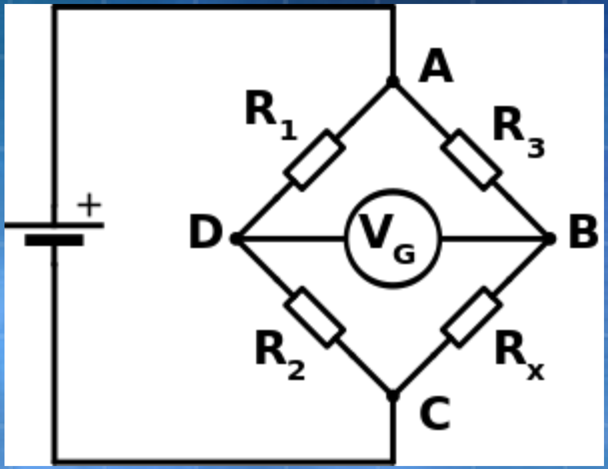
Wheatstone Bridge

- A Wheatstone bridge is an electrical circuit used to measure an unknown electrical resistance by balancing two legs of a bridge circuit, one leg of which includes the unknown component.
- It was invented by Samuel Hunter Christie in 1833 and improved and popularized by Sir Charles Wheatstone in 1843.
- One of the Wheatstone bridge's initial uses was for the purpose of soils analysis and comparison



Wheatstone Bridge Usage

- Rx is the unknown resistance
- R_1, R_2, and R_3 are the known resistance
- If the bridge is balanced then the ratio of $R_2/R_1 = R_x/R_3$, and the voltage and current between Node D and Node B equals zero.
- Or $Rx = R_2/R_1 * R_3$
- Normally R_2 is a variable resistor
- If the bridge is unbalanced, the direction of the current indicates whether R_2 is too big or too small.

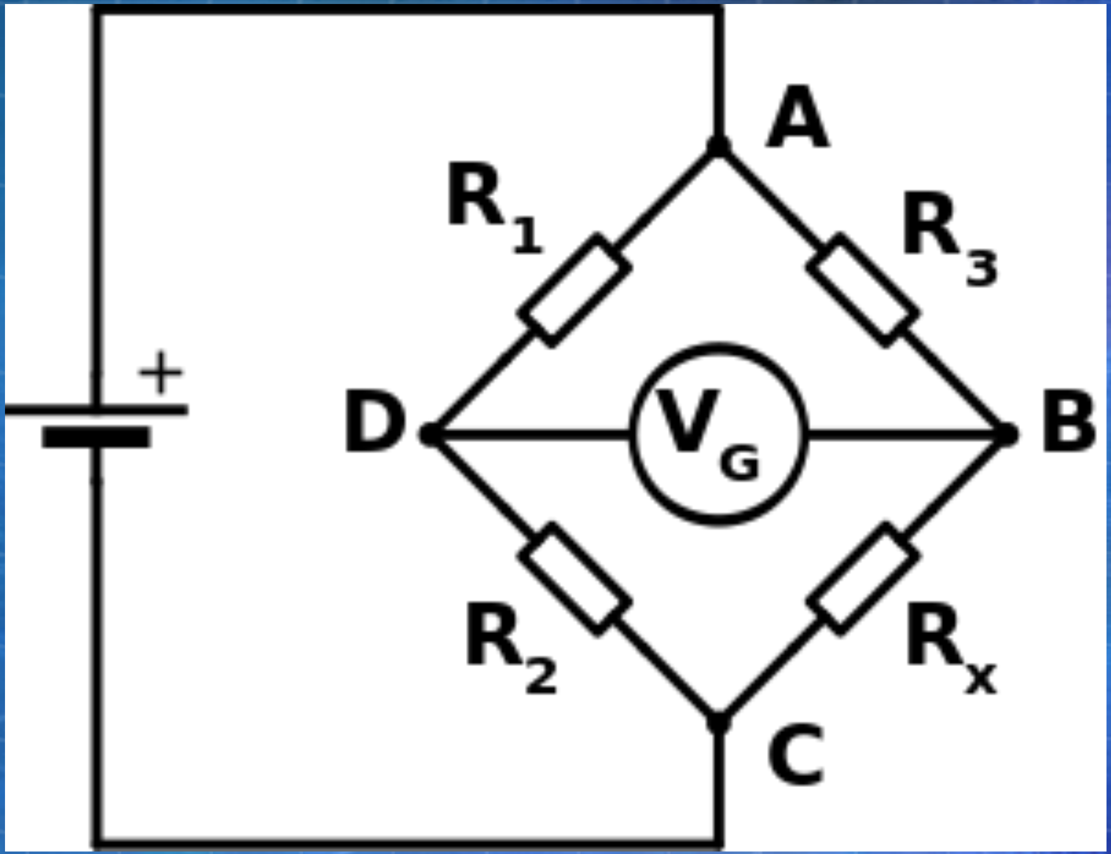


Wheatstone Examples

- $R_1=R_2=R_3=100\Omega$
- $V_D=V_B$, $I_{DB} = 0$ A
- What is R_x

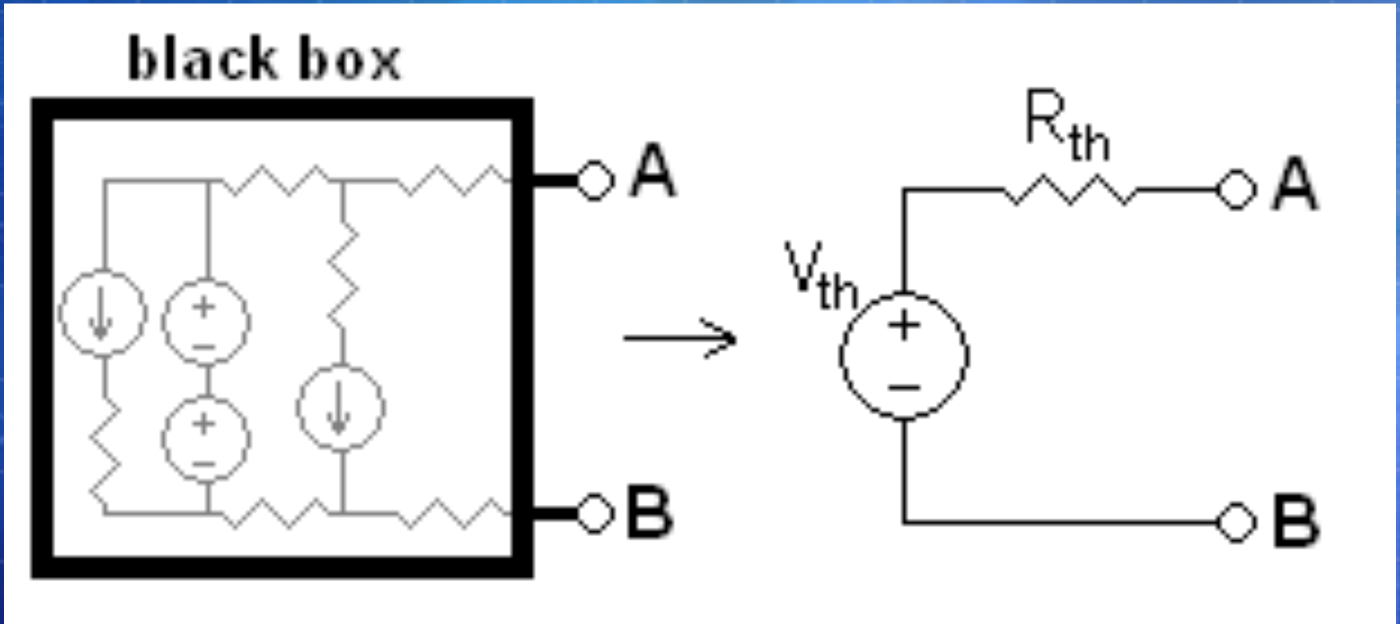
- $R_1=R_2=300\Omega$
- $R_3=200\Omega$
- $V_D=V_B$, $I_{DB} = 0$ A
- What is R_x

- $R_1= 100\Omega$, $R_2=300\Omega$
- $R_3=200\Omega$
- $V_D=V_B$, $I_{DB} = 0$ A
- What is R_x



Thévenin's Theorem/Equivalent

- Thévenin's theorem states that any combination of voltage sources, current sources, and resistors with two terminals is electrically equivalent to a single voltage source V and a single series resistor R.



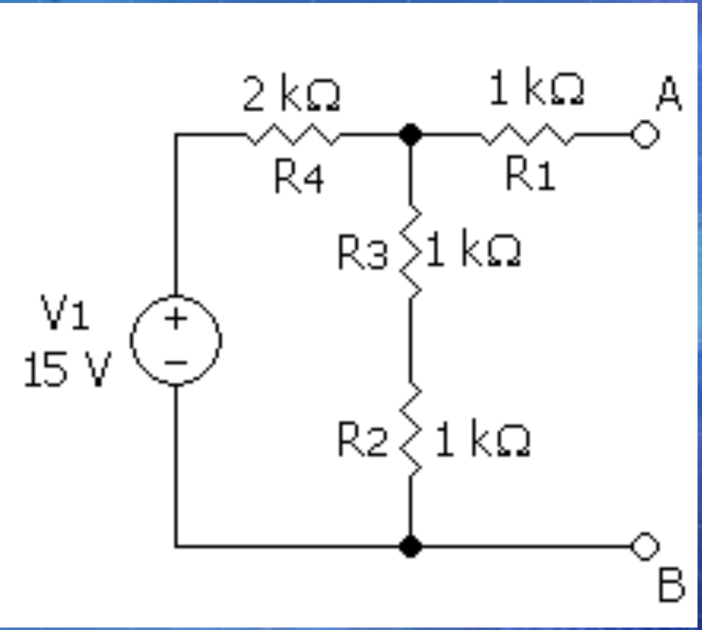
How to find Thévenin Equivalent Values

1. Calculate the output voltage, V_{AB}, when in open circuit condition (no load resistor—meaning infinite resistance). This is V_{Th}.

2. Calculate the output current, I_{AB}, when the output terminals are short circuited (load resistance is 0). R_{Th} equals V_{Th} divided by this I_{AB}.
   - or Replace independent voltage sources with short circuits and independent current sources with open circuits. The total resistance across the output port is the Thévenin impedance R_{Th}.

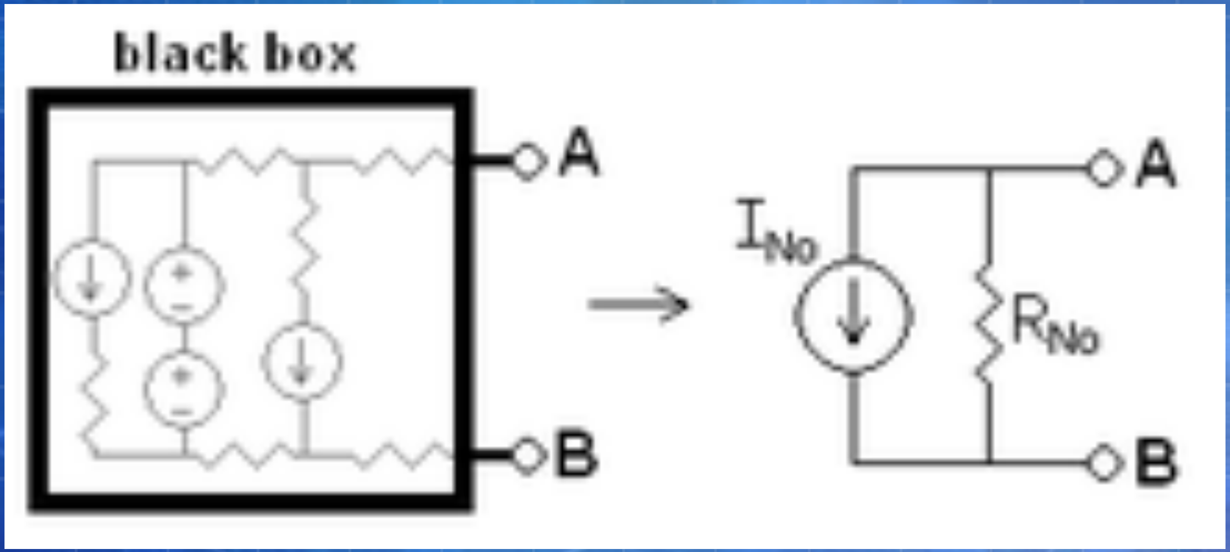
Thévenin Example

- Find V_{th} and R_{th}
- A and B are Open, so no current flows through R_1 and therefore $V_{R1}=0$
- The current from the battery is then $I=V/R_{eq}$
  - $R_{eq}= 2k\Omega + 1k\Omega + 1k\Omega = 4k\Omega$
  - $I=15V/4k\Omega= 3.75mA$
- Using a KVL at the output
  - $Vr2+Vr3=Vr1+Vab=0+Vab=V_{ab}$
  - $Vr2=Vr3=(3.75mA)(1k\Omega)=3.75V$
  - $V_{ab}=3.75V+3.75V=7.5V= V_{th}$
- $R_{th} = R1 + (R4 \text{ in parallel with } (R3 + R2))$
- $R_{th} = 1k\Omega+1k\Omega = 2k\Omega$



Norton's Theorem Equivalent

- Norton's theorem states that any collection of voltage sources, current sources, and resistors with two terminals is electrically equivalent to an ideal current source, I, in parallel with a single resistor, R.



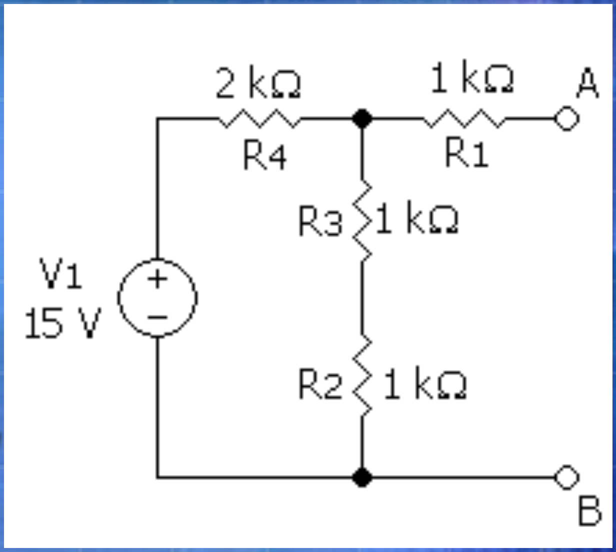
How to find Norton's Equivalent Values

1. Find the Norton current I_{No}. Calculate the output current, I_{AB}, with a short circuit as the load (meaning 0 resistance between A and B). This is I_{No}.

2. Find the Norton resistance R_{No}. When there are no dependent sources (all current and voltage sources are independent), there are two methods of determining the Norton impedance R_{No}.
   - Calculate the output voltage, V_{AB}, when in open circuit condition (i.e., no load resistor — meaning infinite load resistance). R_{No} equals this V_{AB} divided by I_{No}.
   - or <u>Replace independent voltage sources with short circuits</u> and <u>independent current sources with open circuits</u>. The total resistance across the output port is the Norton impedance R_{No}.

Norton Example

- Find I_{no} and R_{no}
- Find current through A and B if shorted
- The current from the battery is then $I=V/R_{eq}$
  - R_{eq} = 2kΩ + 1kΩ in parallel with 2kΩ = 2.67kΩ
  - I=15V/2.67kΩ= 5.625mA
  - I_{ab} = 5.625mA*(2/3)= 3.75mA= I_{no}
  - Removing the power supply with a short, R_{no} is the resistance looking into AB



- R_{no} = 1kΩ + 2kΩ in parallel with 2kΩ = 1kΩ +1kΩ = 2kΩ

How are they related

- $R_{no} = R_{th}$
- $V_{th} = I_{no} * R_{no}$
- $I_{no} = V_{th} / R_{th}$
- Use whichever one makes the problem easier to solve.
- Make sure the current source and resistor are in parallel for Norton
- Make sure the voltage source and resistor are in series for Thévenin

In Practice Sample Competition

Science Olympiad
Exploring the World of Science

- 100 points
- Timed—30 minutes
- Do the following written quiz individually
- You may use <u>any and all notes</u> in your notebook
- You may use your calculator
- Make sure you fill out your name and team at the top of each page
- Tackle the easy problems first, then the tough ones you know how to tackle, then finally the ones you have to guess on.
- If you have time, check your answers

Homework

Science Olympiad

Exploring the World of Science

- Update your binder to get it competition ready
- Complete the circuit problems from the Homework Generator
  - Level 10 Resistors
  - Level 11 Wheatstone
  - Level 14 Norton-Thevenin
- Correct the problems you missed on the practice competition on separate paper.